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A FREQUENCY TRANSLATION SYSTEM FOR STAGE A JINDALEE

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S U M M A R Y

A detailed description of a prototype frequency translator is provided including details of circuits, computed and measured frequency responses of filters, measured performance and fault finding procedures. The translator is used for frequency translating a base band linear FM waveform to a selectable HF carrier frequency.

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1. INTRODUCTION

The function of the Jindalee Waveform Translator is to translate a linear FMCW waveform generated by digital control of a Rockland Synthesiser (1) by a Programmer (2) to the carrier operating frequency of the radar. The Programmer, Rockland Synthesiser, Translator and Fluke Synthesiser comprise what is called the Linear Sweep Generator (LSG).

Different translation systems were developed for the transmitter and the receiver, to meet the operating frequency range requirements which differed between the two sites. The current specifications to which the translators have been constructed are given in Appendix I. Block diagrams of the transmitter and receiver translators are shown in figures 1 and 2.

In response to documentation requirements of the user detailed frequency response data of all the equipment modules are given as far as possible. In addition, explanatory notes on fault finding are given in Appendix II.

2. TRANSLATION SYSTEM FORMAT

2.1 Transmitter and receiver translators

The formats of the translators were determined with overall system requirements in mind. Attention was given to the selection of local oscillator frequencies, selection of filters and amplifiers to minimise mutual interference from harmonics and from the products of multiplication and to provide as much commonality as possible in the design of the overall system. Attention was also given to the signal power levels along the signal translation chain in order to balance susceptibility to spurious leakage signals against dynamic range performance as defined by the two tone test criterion.

2.2 Frequency management chain

The status of this chain was revised during the course of the project. At the time of testing the translation system, this chain was not included as it will not be required until later in the project. Several hybrids were inserted at points along the translator for implementing this chain at a later date.

The function of this chain will be to provide a coherent replica of the radar waveform in the frequency range of 46 to 70 MHz for operation with the Barry Research receiver.

3. TRANSMITTER FREQUENCY TRANSLATION CHAIN - DESCRIPTION

3.1 Input filtering and first mixer stage

The wanted output signal from the Rockland Synthesiser Model 5100 is accompanied by several undesired outputs which have to be eliminated. The first is very close in-band phase noise which appears to be related to the earthing arrangements used within the Rockland. The only effective means of removing the noise was by use of the electro optic isolator. The circuit diagram is shown in figure 3 and frequency performance shown in figure 4. In two of the electro optic isolator units, minor changes in resistor values will be found but the performances achieved correspond closely with that shown on figure 4.

A further undesired output is low level high frequency noise, derived from TTL switching logic driven by an 8 MHz clock. There are distinct

energy peaks at harmonics of 8 MHz and the general noise floor increases above 24 MHz and extends to over 100 MHz. A low pass filter with a 2.2 MHz cut off frequency at the input adequately attenuates the levels of this interference to below 70 dB throughout the band (figures 5 and 6). It should be noted that this portion of the circuitry which is built as an integral part of the first mixer stage was developed prior to the need for the electro optic isolator being identified. The low pass characteristic of this latter unit reduces but does not eliminate the need for the filter.

Another undesired output is the second, third, etc. harmonics of the fundamental. When the fundamental signal is swept to form an FMCW signal, second (45 dB down) and higher harmonic versions are produced. The higher harmonics are partly attenuated by the 2.2 MHz low pass filter. The main attenuation is obtained by choice of local oscillator frequency at the first mixer stage in relation to the band pass frequency of the post mixer filter. A second harmonic sweeping from 2.4 to 2.8 MHz from the Rockland would produce a difference frequency of 2.4 to 2.0 MHz when mixed with the 4.8 MHz local oscillator. Reference to figure 8 shows that this is attenuated 60 dB or more by the 3.45 MHz BPF. In the equivalent receiver case (section 4.1), the local oscillator frequency was chosen as 4.2 MHz to obtain the same effect with a 5.45 MHz filter set at the sum frequency.

The first mixer is a Relcom M9E which is driven by a local oscillator frequency of 4.8 MHz. A 6 dB attenuator is included to ensure a good match to 50 ohms is obtained at the intermediate port of the mixer.

Reference to Table 1 shows the Relcom intermodulation performance. Table 2 shows the interference levels out of the first mixer. The wanted side band is in the 3.4 to 3.6 MHz range. Tables similar to that shown in Table 2 were compiled for each mixer stage for various possible local oscillator frequencies. Out of these came a choice of local oscillator frequencies which were as far as possible chosen to reduce unwanted products. From consideration of the levels of the mixing products, the levels of the reference and local oscillator leakage at the mixer intermediate ports a specification was developed for each band pass filter (BPF) which follows a mixer.

The 3.55 MHz band pass filter is shown in figure 7. This and the other filters to be described were designed using a computer aided design approach (3). It was noted in the report just referenced that top coupling between stages using alternatively capacitors and inductors produced a response with close to arithmetic symmetry - the requirement needed for flat group delay. This design approach was extended to include parallel capacitive and inductive coupling at each stage as seen in figure 7. This approach gave a response closer to arithmetic symmetry than the previous approaches. The inductance values were determined empirically but the combined reactance of the parallel combination equals the reactance of the original coupling capacitors given by the band pass filter computer aided design approach. This approach to top coupling was used on the 3.55 MHz BPF where the need for a narrow bandwidth made minimisation of group delay variation difficult. Figures 8 to 10 detail frequency characteristics. See also Appendix III for general procedures for alignment of filters.

3.2 Second mixer stage (transmitter)

The input to the mixer is fed by the output of a 10 dB gain wideband amplifier (see Appendix IV). The amplifier, mixer and 6 dB pad are constructed in a single enclosure, labelled second mixer. This mixer translates the 3.6 to 3.4 MHz input to 18.6 to 18.4 MHz through use of a 15 MHz local oscillator. The circuit diagram of the 18.45 MHz BPF is shown in figure 11, while the computed and measured amplitude response and

computed group delay and measured phase characteristics are shown in figures 12 through 16. The computed graphs are shown here by way of illustration of the design approach. Only the measured responses of the remaining filters to be discussed will be included.

Note that there is a series resonant notch filter to ground at 15 MHz. This is to further reduce the level of 15 MHz local oscillator signal which appears at the input of the filter from the previous mixing stage.

3.3 Third mixer stage (transmitter)

The third mixer unit is identical in construction to the second. The local oscillator is at 64 MHz so that the output is in the range of 82.6 to 82.4 MHz. The output of the mixer is applied to an 82.45 MHz BPF. The circuit diagram and measured performance of this filter is shown in figures 17 through 20.

3.4 Fourth mixer stage (transmitter)

The fourth mixer stage is identical in construction to the second and third mixer stages, except that the output pad has 12 dB attenuation. The mixer is fed directly with the output of the Fluke Synthesiser Model 6160A set at a frequency of (82.6 - F) MHz where F is the required output frequency.

3.5 Output stages (transmitter)

The output of the mixer stage is amplified by two SRI type amplifiers (see figure 21) which have characteristics similar to those shown in figure 22. A low pass filter (figure 23) located between the amplifiers was used to remove the upper sideband of the mixing process and to pass the output signals which fall in the 5 to 30 MHz range. The performance of the filter is shown in figure 24.

4. RECEIVER FREQUENCY TRANSLATION CHAIN

4.1 Low pass filter and first mixing stage (receiver)

The output of the Rockland is fed via an attenuator and electro optic isolator to a low pass filter then a pad, mixer and pad. This arrangement is similar to figure 5. In a manner similar to the transmitter, the choice of 4.2 MHz allows adequate attenuation of the second harmonic from the Rockland which, already partially attenuated by the input low pass filter, is further attenuated by the skirts of the 5.45 MHz BPF.

The output of this stage is fed to a 5.45 MHz band pass filter (figure 25). The response curves for this filter are shown in figures 26 to 28.

4.2 Second mixing stage (receiver)

This stage follows the standard format, the local oscillator in this case is 24 MHz. The circuit diagram of the 29.4 MHz BPF is shown in figure 29 and the measured responses are shown in figures 30 to 32.

4.3 Third mixing stage (receiver)

This stage follows the standard format, the local oscillator frequency is 75 MHz. The circuit diagram of the 104.4 MHz filter is shown in figure 33, and figures 34 to 36 show measurements of the filters insertion loss, both in the pass band and wideband, as well as its phase characteristics in the pass band region.

4.4 Fourth mixing stage (receiver)

This stage has no amplifier and the mixer is preceded by a 9 dB pad. The Fluke Synthesiser provides local oscillator signals at a frequency of (104.4 +F) MHz, where F is the required output frequency from the translator.

4.5 Output circuits (receiver)

The output circuits consist of broadband amplifiers (figure 21), a 68 MHz low pass filter (see figures 37 to 39), and a pad in series (see figure 2).

5. LOCAL OSCILLATOR CHAINS

These produce the coherent local oscillator frequencies necessary for the frequency translation. From a review of the various synthesis techniques available, it was decided that a step recovery diode (SRD) harmonic generator followed by selective filtering, afforded the best approach for this application. Once selected, it was decided to maintain the approach throughout the whole local oscillator chain rather than to mix techniques, such as use of transistor doublers as could have been used in, for example, the multiplication from 12 to 24 MHz. This streamlined the construction, by allowing manufacture of printed circuit SRD boards for all stages, and should simplify fault finding and maintenance tasks.

5.1 Step recovery diode multipliers

The frequency multiplication technique uses step recovery diodes to produce a comb of frequencies spaced at the driving frequency and extending over a wide frequency range. Tuned amplifiers followed by band pass filters were used to select the desired frequency. Frequencies and filtering were chosen to ensure that the output signals were free from spurious signals measured over a 70 dB dynamic range.

Initially two different circuits were used (see figures 40 and 41), one optimised for lower input frequencies (typically 1 to 5 MHz), while the other optimised for higher input frequencies of 16 MHz and above. Later a circuit (figure 42) was developed which operates very well over the whole of the range of input frequencies. A number of these units have been provided as spares and, where the opportunity has arisen, they have been used to replace the previous types.

6. LOCAL OSCILLATOR FREQUENCY SYNTHESIS - TRANSMITTER

The local oscillator chains shown in the block diagram of figure 1 will be described in detail in the following sections.

6.1 4 MHz generation (transmitter)

The 1 MHz reference sine wave is fed via a matching network (to minimise loading of the frequency reference unit) and an isolation transformer to the R port of an HP 10534C mixer. The 5 MHz reference output from the Fluke Synthesiser is resistively split and one output is fed to the L port of the HP 10534C (see figure 43). The 4 MHz difference signal is filtered and amplified in a tuned filter (figure 44).

The output of the 4 MHz band pass amplifier unit is fed via two internal buffer stages to two outputs (one with an isolation transformer) to a 4.8 MHz conversion unit and a 4 to 16 MHz amplifier.

6.2 4.8 MHz generation (transmitter)

This circuit (figure 45) takes the 4 MHz buffered output from the 4 MHz amplifier circuits. The outputs are voltage translated to TTL logic levels and applied in one case to a divide by five circuit, the output of which feeds an exclusive OR multiplier (7486), while in the other case the squared output directly feeds the exclusive OR. The output from the exclusive OR is applied via a parallel tuned circuit at 4.8 MHz to an MC1590 tuned amplifier, a single stage amplifier and buffer.

The output is fed to a 4.8 MHz BPF. The performance curves are shown in figures 46 and 47.

6.3 16 MHz generation (transmitter)

The circuit is shown in figure 48. The format is similar to that already described. The amplifiers are matched with the dynamic resistance reflected from the output to be such as to give the power gain required.

The 16 MHz band pass filter is shown in figure 49 and the theoretical and measured performance is shown in figures 50 and 51.

6.4 64 MHz generation (transmitter)

The circuit is shown in figure 52. The circuit uses a "high frequency" SRD circuit followed by an MC1590 amplifier. This matches into a 2N 4073 single stage amplifier of nominal 10 dB gain. This in turn feeds the output stage consisting of an MM1552 with DC biasing via the 2N2905. This configuration gives excellent stability and linearity but has a low input impedance - that is the input impedance of the MC1552. Thus the interstage matching network transforms the low impedance of the MM1552 into a dynamic impedance adequate to obtain the 10 dB gain requirement for the 2N4073 stage. The output matching network of the MM1552 stage is designed to provide a 50 ohm match at the output. The band pass filter is shown in figure 53 with the measured performances in figures 54 and 55.

6.5 15 MHz local oscillator synthesis - transmitter

The reference input is obtained via an isolation transformer from the buffered 5 MHz output from the Fluke Synthesiser. Similar techniques to those already discussed were used. The 15 MHz amplifier is configured similarly to the 64 MHz amplifier discussed in section 6.4.

Figure 56 shows the circuit of the 15 MHz amplifier, while figures 57 to 59 show the band pass filter circuit and its measured performance.

7. LOCAL OSCILLATOR FREQUENCY SYNTHESIS - RECEIVER

The local oscillator chains shown in the block diagram of figure 2 will be described in detail in the following sections.

7.1 4.2 MHz generation (receiver)

To generate 4.2 MHz, a buffered and isolated 1 MHz reference signal is mixed with 3.2 MHz and the sum component selectively amplified and filtered.

The 1 MHz input is obtained via the 4 MHz unit (see section 7.2). The 3.2 MHz is obtained by dividing 16 MHz by five. The circuit (figure 60) consists of a fast comparator (μA760) which acts as a squarer to the incoming sine wave, a voltage translation transistor stage, an SN7490 connected to divide by five and an LH0002C buffer. The 3.2 MHz and 1 MHz are the inputs to the 4.2 MHz mixer-amplifier (figure 61).

The 1 MHz input to the mixer is applied via a 5 section, 1 MHz cut off

low pass filter. The level is then reduced to a suitable value for feeding the R port of the mixer. The 3.2 MHz square wave is applied at the LO port. The output sum term of 4.2 MHz is selectively amplified to a mixer drive level. This stage caused difficulties because of spurious interference signal which occurred 200 kHz high of the 4.2 MHz output. It was established to be due to the second harmonic of the 1 MHz mixing with the second harmonic of the local oscillator frequency. Thus 2 and 6.4 MHz gave an inband 4.4 MHz difference frequency. By use of the sharp cut off filter, the second harmonic of the 1 MHz signal was adequately reduced to solve the problem. However, a requirement remains that the 1 MHz reference supplied must have a second harmonic component better than 40 dB down at the input to the unit (that is at the input to the low pass filter).

The output of the 4.2 MHz stage is filtered in a band pass filter, the characteristics of which are shown in figures 62 and 63.

7.2 4 MHz generation (receiver)

The 1 MHz reference input to the unit is also taken internally to a buffer and isolating transformer and appears as an output along with the buffered 4 MHz outputs (see figure 64).

7.3 12 MHz generation (receiver)

This is an intermediate stage in the generation of a 24 MHz local oscillator signal. The stage follows the same format as other multiplier stages, the relevant circuit, filter and filter performance are shown in figures 65 to 68.

7.4 24 MHz generation (receiver)

This circuit (figure 69) provides a drive at a level (after filtering) of +18 dBm to the second mixer stage. The output circuit is the same as that described in section 6.4 for the generation of relatively high mixer local oscillator signals. The circuit diagram and the filter performance curves are shown in figures 70 to 72.

7.5 15 MHz generation (receiver)

This is an intermediate stage in the generation of the 75 MHz mixer local oscillator drive. The relevant circuit diagrams and filter curves are shown in figures 73 through 75.

7.6 75 MHz generation (receiver)

The circuit (figure 76) supplies a level of +20 dBm to the third mixer stage after filter loss. The output circuit is the same as that described in section 6.4 for the generation of relatively high level mixer local oscillator signals. The filter performance curves are shown in figures 77 and 78.

8. SPECTRAL PERFORMANCE

(i) CW signal spectral purity

For operation with the translator in the CW mode, the Hewlett Packard 141T series spectrum analyser was used for assessment of translator phase noise levels.

Figure 79 shows the type of spectrum, figure 79 (a) was taken in the laboratory for a 25 MHz CW output with 50 Hz/div sweep width, while figure 79 (b) is for an 18 MHz carrier, sweep width 100 Hz/division, taken

at the Harts Range transmitter site. This latter figure shows retention of good phase noise performance after nine months of operation in the field. Evidence of 50 Hz and 150 Hz lines can be seen in the photographs. However, the actual amplitude is marked by a contribution to these lines by the spectrum analyser itself as shown in figure 80. This is a photograph of the spectrum of the 5 MHz output from a Hewlett Packard 105B frequency standard, battery operated, taken in a screened room with the spectrum analyser being the only AC powered equipment in operation. The 50 Hz and 150 Hz lines clearly must originate within the spectrum analyser and are possibly present on its local oscillator signals.

(ii) Linear FM spectrum

Figure 81 shows examples of the spectrum of the linear FM signal obtained from a translator, for an FMCW input at two representative sweep rates.

(iii) Deramped spectrum

In practice, the received linear FM signal from the receiving antenna system is deramped at the first mixer of the receiving chain, the local oscillator being a frequency translated version of the receiving system's linear sweep generator output. The deramped signal is successively mixed, filtered and amplified through the receiving system and is finally applied to a 12 bit A-D converter. A Fast Fourier Transform analysis is used to provide the spectrum of the deramped signal. The corresponding laboratory test is to apply the attenuated output of the transmitter LSG to the antenna input of the receiving system and by suitable synchronising of the transmitter and receiver LSG's to obtain a deramped signal in the pass band of the final receiver stage. This signal is deramped and it is the spectral performance of this signal which determines the radar's sensitivity. The following results were obtained in the laboratory, shortly before the equipment was transferred to the radar sites.

Figure 82 shows the format of the printout showing noise levels of successive deramped signals (50 Hz repetition rate) at 15 points each side of the central peak. A histogram of these noise levels on the low and high side of the central peak (HISTLO and HISTHI) are given at the base of the printout. The spectrum in approximately 1.2 Hz resolution bandwidth averaged over 10 of these sweeps is shown in figure 83. Range sidelobes are shown 50 Hz away from the central peak. Figure 84 shows an unsmoothed spectrum (corresponding to the last entry in the printout of figure 82) taken over a wider bandwidth, where the fall off in range sidelobes are evident.

Figures 85, 86 and 87 show the corresponding performance for a nominal 60 Hz repetition rate. The presence of 50 Hz (electrical mains frequency) modulation is evident as low level peaks spaced $\pm$ 50 Hz from each of the major peaks.

9. CONCLUSIONS

At the time of writing the LSG has been operating reliably and within specification in the field for almost a year.

The equipment described herein was a first prototype, commenced early in the Stage A program and was the subject of modifications as the experience and the requirements of the overall radar developed and as its interaction with

other equipment became defined. Inevitably, it is not the most economical approach to what has now evolved as the system needs. However, the effectiveness of the circuit techniques has been demonstrated and simpler configurations for meeting current requirements have been designed and successfully demonstrated in the laboratory. An example is a local oscillator format using harmonically related frequencies and broadband mixer drivers. The prototype equipment development described in this report provides the basis needed for the construction of a second generation LSG to the significantly tighter specifications which have recently been issued to meet new radar detection objectives.

10. ACKNOWLEDGEMENTS

There were numerous contributors who assisted in the development, construction and evaluation of this equipment. Mention should be made of the assistance from Jindalee Project Group staff, particularly Ricky Grivell (RF amplifier development and construction), Peter Hattam (filter construction), Mike Denison, Bruce Carter and Dennis Miller (construction of various subsystems), and Dr Malcolm Golley who wrote and ran the spectral analysis programs used to obtain the results of section 8.

Also members of Radio and Electronic Tracking Group, Marian Viola (consultation on RF matching techniques) and Paul Dansie and Daryl Ireland for assistance in the later stages of LSG integration into the radar system.

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APPENDIX I

RADAR LINEAR SWEEP GENERATORS FOR RECEIVER AND TRANSMITTER SITES

1. GENERAL

The function of the equipment is to generate a linear phase continuous FM waveform with selectable initial frequency, sweep rate and repetition rate. The equipment is to operate under either manual or computer control. A block diagram is given in figure I.1 which shows the four components of the generator.

The JINDALEE Digital Programmer (see figure I.1) is to control a Rockland 5100 synthesiser to generate a repetitive linear FM waveform, phase continuous through each sweep, which is subsequently translated to the required frequency region using the JINDALEE Frequency Translator and a Fluke 6160B synthesiser.

The transmitter site generator is to operate in the nominal range 6 to 30 MHz whereas the receiver site generator is to operate in the nominal range 26 to 50 MHz, the frequency displacement being due to the LO drive arrangements for the radar receivers. The generators are also to provide a back up capability for the backscatter sounder linear sweep generators.

Manufacturers specifications for the Rockland and Fluke synthesisers are given in Annexes A and B respectively. Specifications for the Digital Programmer and Frequency Translator are given below.

2. REFERENCE SIGNALS

Separate reference signals are to be accepted as follows.

2.1 Digital Programmer

1 MHz TTL compatible square wave : from Rockland Synthesiser.

2.2 Rockland 5100 Synthesiser

1 MHz TTL compatible square wave, close to unity mark-space ratio : from Reference Frequency Distribution System.

2.3 Frequency Translator

1 MHz sine wave, 1 volt RMS, source impedance 50 ohms, second and higher harmonics to be at least 40 dB down in the fundamental : from Reference Frequency Distribution System.

5 MHz wine wave, 1 volt RMS, source impedance 50 ohms : from Fluke Synthesiser.

2.4 Fluke 6160B Synthesiser

5 MHz sine wave, 1 volt RMS, source impedance 50 ohms : from Reference Frequency Distribution System.

3. JINDALEE DIGITAL PROGRAMMER

The programmer is to control the Rockland 5100 synthesiser to produce a linear phase continuous waveform as follows.

3.1 Rate of frequency sweep

3.1.1 Manual control

Control by a single 4 position switch, giving sweep rates of 100, 200, 500 and 1000 kHz/sec with frequency steps of 0.1, 0.2, 0.5 and 1 Hz respectively.

3.1.2 Computer control

By a 4 bit binary system comprising TTL compatible DC voltage levels on four control lines according to the table below :

Computer Output				Sweep Rate kHz/sec.	Frequency Step Hz
Line 1 LSB	Line 2 2nd LSB	Line 3 3rd LSB	Line 4 4th LSB		
1	0	0	0	1000	1
1	0	1	0	500	.5
1	1	0	0	200	.2
1	1	1	0	100	.1
0	1	1	0	$33\frac{1}{3}$	
0	1	1	1	1.2 MHz constant output frequency	
1	0	0	0	When sweep starting frequency is varied (see paragraphs 3.2 and 3.9 below)	

Logic level 1 ~ +5V
Logic level 0 ~ 0V

3.1.3 Displays

LED displays are to be provided showing which sweep rate has been selected.

3.2 Sweep starting frequency

The sweep is to commence with a starting frequency of 1.2 MHz unless varied under control of the sweep commencement circuit (see paragraph 3.9 below).

3.3 Sweep repetition rate

Sweep to sweep repetition accuracy is to be of the order of 10 nsec.

3.3.1 Manual control of sweep repetition rate

Thumb wheel switch control with settings reading directly in sweeps per second, and covering the range 2 to 120 sweeps per second in increments of 1 sweep per second.

3.3.2 Computer control of sweep repetition rate

By a TTL compatible negative going pulse train from the timing equipment and covering a range from at least 1 sweep every 15 seconds to 120 sweeps per second. The pulse width should be 300 nsec, and the negative going edge should be at least 100 nsec away from the positive going edge of the 1 MHz reference of paragraph 2.1 above. The pulse train is to be delivered through a twisted pair fed from a line driver type DM8830 or equivalent.

3.4 Computer/manual control

A single master switch which switches the whole of the operation of the Programmer to either computer or manual control.

3.4.1 Computer/manual status signal

The Programmer is to provide a TTL compatible logical zero level to the computer when the Programmer is set to computer control.

3.5 Synchronisation of receiver and transmitter waveforms

3.5.1 Manual synchronisation

Provision is to be made for the sweeping waveform to be reset on the arrival of an external trigger. The external trigger is to be accepted from the timing equipment and is to comprise a TTL compatible positive going pulse train at a 1 Hz rate. Provision is also to be made for the start of the reset waveform to be delayed subsequent to the arrival of the external trigger. The delay is to be variable in 1 msec steps from 0 to 30 msec by thumbwheel switches, the settings of which are to read directly in msecs. The delay facility is normally to be used only at the receiver site.

3.5.2 Computer synchronisation

To be achieved by the computer by delaying the sweep repetition rate control pulse train (see paragraph 3.3.2 above) delivered to the Linear Sweep Generator at the receiver site by the required amount.

3.6 Sweep starting phase angle

Each sweep to start from zero phase angle.

3.7 Noise and spurious signals

See paragraph 4.3.3 below.

3.8 Additional outputs

A connector is to be provided to make the Rockland frequency programming voltages available for external use. A mating connector is also to be provided.

3.9 Sweep commencement frequency

A facility is to be provided to allow the sweep commencement frequency to be varied under computer control.

The process is to provide a linear ramp in starting frequency over the dwell time by incremental additions to the programmed frequency of the Rockland Synthesiser. The linear ramp in starting frequency is to commence from zero hertz and reach a value equal to the repetition rate of the radar at the end of the dwell time. (This linear ramp in starting frequency is added to the normal starting frequency of 1.2 MHz.) In addition, the frequency is to increment in steps equal to the inverse of the dwell time. The computer is to provide the computed starting frequency data in a static state prior to the commencement of each sweep in accordance with the table below. The Programmer is to provide the means of interfacing this data with its counter stages and with the remote programming inputs to the Rockland Synthesiser.

The sweep commencement data is to be provided in a binary format compatible with the remote control code for the Rockland Synthesiser.

Starting Frequency	Programming Lines	Byte Number	
		Table 2	Table 3
Millihertz	Binary (8 bits)	33	31
	Binary (2 bits)	34	32
Hertz	Binary (7 bits)	35	33

The maximum repetition rate is 120 Hz so that only seven lines of hertz data are required.

The waveform sweep rate is to be 1 MHz/s in all cases in which the starting frequency is varied. The computer is therefore to provide sweep rate control for 1 MHz/s as indicated in the table in paragraph 3.1.2 above.

4. JINDALEE FREQUENCY TRANSLATOR

4.1 Synthesiser signals from Rockland 5100

Modulated signal as detailed in paragraph 3 above, level - 20 dBm, source impedance 50 ohms.

4.2 Synthesiser signals from Fluke 6160B

4.2.1 Level

CW signal, 1 volt RMS, source impedance 50 ohms.

4.2.2 Frequency and sweep slope

In accordance with the following table where F is the required output starting frequency of the translator as specified in paragraph 4.3.5 below.

Translator	Fluke Frequency	Sweep Slope
Transmitter site	82.6 - F MHz	Negative
Receiver site	104.4 + F MHz	Negative

Note that the Fluke setting at the Receiver site corresponding to F at the Transmitter site is given by : 124.45 + F + required receiver baseband frequency.

4.2.3 Computer control

See manufacturer's data in Annex B.

4.3 Output signal

4.3.1 Source impedance

50 ohms nominal.

4.3.2 Level into 50 ohm load

Sine wave at 1 volt RMS, varying less than + 1.5 dB over the required output frequency range and less than 1.5 dB peak to peak over any 500 kHz sweep.

4.3.3 Noise and spurious signals

Spurious signals and noise power in a 1 Hz bandwidth to be more

than 70 dB below the nominal output power level.

4.3.4 Group delay

Variation to be less than 500 nsecs peak to peak over any 500 kHz sweep.

4.3.5 Frequency limits

(a) At the transmitter site

5.75 - 30.25 MHz, i.e. centre frequency of maximum sweep in the range 6 - 30 MHz.

(b) At the receiver site

25.75 - 50.25 MHz, i.e. displaced 20 MHz from transmitter site frequencies.

4.4 Dimensions

To suit standard 19" rack, 2 units for each translator, each of panel height $5\frac{1}{4}$".

ANNEX A

MANUFACTURER'S DATA ON ROCKLAND 5100 FREQUENCY SYNTHESISER

FREQUENCY	
Range	0.001 Hz to 2,000,000.000 Hz
Resolution	0.001 Hz throughout entire range
INTERNAL CRYSTAL	
Temperature stability	$\pm$ 2 x $10^{-8}/^{o}C$ typical from 0^{o} to $50^{o}C$
Aging rate	1 part in 10^{8} per day 1 part in 10^{6} per year
External reference	Accepts external 1 MHz reference with TTL levels. Loading is one standard TTL load. Rear panel BNC jack.
OUTPUT SIGNALS	
1 MHz reference output	Square wave with TTL levels capable of driving 30 standard TTL loads. Rear panel BNC jack.
Fixed output	Approximately 1 volt P-P with 50 ohm source impedance. Front and rear panel BNC jacks.
Variable output	10 volts P-P maximum with 50 ohm source impedance. Front and rear panel BNC jacks.
Attenuator	Provides from 0 to 85 dB attenuation of the variable output signal in steps of 1 dB. Front panel pushbutton control.
Level control	Continuous control of the variable output signal from zero volts to full output at any given attenuator setting.
VARIABLE OUTPUT SIGNAL	0.001 Hz, 100 kHz, 500 kHz, 2 MHz
RMS FRACTIONAL DEVIATION	
10 msec averaging 1 sec averaging	5 x 10^{-7} 5 x 10^{-9}
PHASE NOISE	
In 30 kHz band excluding 1 Hz centred on carrier	- 50 dB
SPURIOUS COMPONENTS	- 70 dB, - 60 dB, - 50 dB
HARMONIC COMPONENTS	
At 1 volt RMS output At full output	- 55 dB, - 50 dB, - 45 dB - 55 dB, - 50 dB, - 40 dB
FREQUENCY RESPONSE (FULL OUTPUT)	
No load 50 ohm load	$\pm$ .25 dB, $\pm$ .5 dB $\pm$ .25 dB, + .5 dB, - 2.5 dB
ATTENUATOR RESPONSE (TO 60 dB)	$\pm$ .5 dB

REMOTE PROGRAMMING

Frequency selection	31 bits in binary or 37 bits in BCD format. Format selected by one control bit.
Loading sequence	Synchronous loading of all frequency and attenuation bits in one parallel word, or in four 12 bit bytes. Sequence selected by one control bit.
Remote mode selection	Via front panel pushbutton or one control bit. Front panel lamp indicates remote mode.
Programming delay	1.5 μsec for binary-word with phase and amplitude continuity maintained. 20 μsec for BCD-word with output reset to zero phase during delay. 20 μsec minimum for four BCD or binary bytes with output reset to zero phase during programming.
Update rate	625 nanosec for binary-word. 18 microsec for BCD-word and BCD or binary-byte.
Zero phase reset	Output maybe asynchronously reset to zero phase via one control bit. The response time to and from zero phase is 800 nanosec. This line may also serve as a load acknowledge output.

ELECTRICAL AND PHYSICAL

Operating temperature	$0^{o}C$ to + $50^{o}C$ ambient
Storage temperature	- $20^{o}C$ to + $70^{o}C$
Power requirements	115 or 230 volts AC, $\pm$ 10% 50-60 Hz, 65 watts.
Size	$3\frac{1}{2}$"H x 17"W x 13"D
Weight	21 lbs shipping, 25 lbs.
Accessories supplied	Rack adaptors, programming connector, instruction manual.

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ANNEX B

MANUFACTURER'S DATA ON FLUKE 6160B FREQUENCY SYNTHESISER

NOTE: Model 6160B is the same as Model 6160A Option 03

FREQUENCY	
Ranges	1 MHz to 12 MHz, 10 MHz to 160 MHz
Increments	100 Hz (0.1 Hz with 03 Option) 1 kHz (1 Hz with 03 Option)
Selection	Front panel rotary switches, remote BCD-TTL or DTL positive true logic or contact closures. Logic "0" = 0 to + .9 V DC. Logic "1" = + 2 to + 5 V DC or open circuit. (See Table 1).
SPURIOUS OUTPUTS	
Non-harmonic	Greater than 75 dB (to 100 dB) below fundamental.
Harmonics	Greater than 25 dB below fundamental. (Typically > 30 dB).
SIGNAL TO NOISE RATIO (TYPICAL) (Including the effects of the internal standard)	
Phase	Greater than 62 dB
Amplitude	Greater than 94 dB
SYNTHESISER RESIDUAL (Internal noise from 5 MHz input to synthesiser output)	
Phase	Greater than 74 dB
Amplitude	Greater than 94 dB
	Measured in a 30 kHz band excluding a 1 Hz band centred on the fundamental for dialed frequencies from 80 MHz to 160 MHz. Improvement in signal to phase noise ratio is seen for lower frequencies.
PHASE NOISE SPECTRAL DENSITY	Guaranteed SSB S/N ratio at the synthesiser output measured in a 1 Hz bandwidth. Valid for dialed frequencies from 80 MHz to 160 MHz. Improvement for lower selected frequencies.

Offset frequency	Guaranteed S/N
1.2 kHz	>115 dB
40.0 kHz	>124 dB
600.0 kHz	>135 dB

OUTPUT VOLTAGE	
1 MHz - 160 MHz	Adjustable from + 3 dBm to + 13 dBm into 50 ohm (.3 V to 1 V RMS) with front panel control or external DC voltage. Level maintained ± 1 dB into 50 ohm.
SWITCHING TIME	Less than 500 μsec to be within 100 Hz of final frequency. Less than 2 msec to be within 10 Hz with Option 03 is installed.
POWER REQUIREMENTS	115/230 V RMS ± 10% selectable by rear panel switch, 50 - 500 Hz, 80 watts.

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DIMENSIONS, WEIGHT	Standard 19" (48.3 cm) relay rack width, 7" (17.8 cm) high, 20" (50.8 cm) behind front panel, 45 pounds (21 kg). Slides and rack mounting kit optional.
ENVIRONMENTAL	
Operating	0 to 50°C, 0 to 80% RH, 0 to 10,000 feet.
Non-operating	-62°C to +70°C, 0 to 50,000 feet.
AUXILIARY OUTPUTS	5 MHz at nominally 1 V RMS into 50 ohm
AUXILIARY INPUTS	External 5 MHz frequency standard at 1 V RMS nominal into 50 ohms. External level control voltage - approximately +0.1V to +0.8V DC. Input resistance > 2 kohms.

TERMINAL	FUNCTION	
1		Power flag : Logic "0" = Power off Logic "1" = Power on
2		Spare
3		) Key
4		)
5		Range : Logic "0" = 1-12 MHz Logic "1" = 10-160 MHz
6		)
7		) Logic GND
8		)
9		Spare
11		Remote flag : Logic "0" manual Logic "1" remote
12		Spare
	Bit	Decade (range)
10	1	100 MHz (10-160 MHz) 10 MHz (1-12 MHz)
14	1	)
13	2	) 1 MHz (1-12 MHz)
16	4	) 10 MHz (10-160 MHz)
15	8	)
18	1	)
17	2	) 100 kHz (1-12 MHz)
20	4	) 1 MHz (10-160 MHz)
19	8	)
22	1	)
21	2	) 10 kHz (1-12 MHz)
24	4	) 100 kHz (10-160 MHz)
23	8	)
26	1	)
25	2	) 1 kHz (1-12 MHz)
28	4	) 10 kHz (10-160 MHz)
27	8	)
30	1	)
29	2	) 100 Hz (1-12 MHz)
32	4	) 1 kHz (10-160 MHz)
31	8	)
34	1	)
33	2	) 10 Hz (1-12 MHz)
36	4	) 100 Hz (10-160 MHz)
35	8	)
38	1	)
37	2	) 1 Hz (1-12 MHz)
40	4	) 10 Hz (10-160 MHz)
39	8	)

TERMINAL	FUNCTION	
	Bit	Decade (range)
42	1	
41	2	0.1 Hz (1-11 MHz)
44	4	1 Hz (10-160 MHz)
43	8	

REMOTE FREQUENCY CONTROL

(TOP)

2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44
1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43

(BOTTOM)

TABLE 1 - REMOTE FREQUENCY CONTROL CONNECTOR TERMINALS

APPENDIX II

FAULT FINDING PROCEDURES

1. With the Programmer switched off and the Rockland set to 1.2 MHz in the manual control position, the output signal from the LSG should be an unmodulated carrier at a level of +13.7 ± 0.7 dBm in the case of the receiver LSG. In the transmitter case, it has become the practice to run the LSG at a higher output level of +20 dBm. The input and inter-stage signal levels are shown in figures 1 and 2. The output power may be adjusted by use of the attenuator controls on the front panel of the Rockland Synthesiser.

2. The output signal can be monitored on a spectrum analyser. The spectral performance should be similar to that shown in figure 79 and be in accord with the Specification JIN/R/21.

3. With the Programmer switched on, set the control selection switch on the Rockland to remote, choose a 500 kHz/sec sweep rate and 50 Hz repetition rate, and monitor on a spectrum analyser, the spectrum should have the appearance of that shown in figure 81.

4. If there is no output signal, the following check procedures should be followed :

   (a) Check that the front panel settings of the Rockland and the Fluke are correctly set.

      (i) If the manual control is required with the Rockland, sweeping controls on the Rockland and the Fluke and the Programmer must be set to 12-160 MHz (i.e. not remote), remote and manual respectively.

      (ii) Check the frequency settings of the Fluke -

      Transmitter : Fout = 82.6 MHz - (Fluke setting)
      Receiver : Fout = Fluke setting - 104.4 MHz.

   (b) If there is still no output signal, turn off the Programmer, set the Rockland to manual mode and a frequency of 1.2 MHz and, by use of a spectrum analyser or power meter, carry out the appropriate checking procedure indicated in figures 2-1 and 2-2. The power levels are shown in figures 1 and 2.

APPENDIX III

ALIGNMENT OF BANDPASS FILTERS

The following is a resume of section 9.4 reference 4 and contains instructions necessary for alignment of the LC bandpass filters used in the LSG Translator at the transmitter and receiver site.

Included with the design data for each bandpass filter are the frequencies necessary for the alignment of the bandpass filters using the method described below. The procedure enables significant components to be independently adjusted to the correct value while in their final location.

All the filters were aligned using a General Radio type 1710 Network Analyser. However, it should be possible to align a filter to its specification using a good sweep generator and sensitive detector. It was necessary to have a display of the passband characteristic to make final adjustments to meet the passband specification for some of the filters.

The alignment procedure described here is applicable to filters where the unloaded Q's of individual resonators is greater than 4 or 5 times the overall Q of the filter $\left(\frac{fo}{BW_{3\ dB}}\right)$. This condition is satisfied for all of the bandpass filters used in the LSG Translator.

ALIGNMENT PROCEDURE

1. Use component values close to desired value and completely assemble the filter to its final configuration but with access to component adjustments still possible.

2. Detune all but the first resonator section with a short circuit on each resonator section.

3. Connect 50 ohm sweep generator to input of filter and loosely couple the detector directly to the electric or magnetic field of the first (input) resonator. Coupled signal should be at least 20 dB down to ensure there is no significant loading on the resonator section.

4. Adjust input impedance matching capacitors to obtain the 3 dB bandwidth required and the peak response at the filter centre frequency.

5. Remove the short circuit from the second resonator and adjust the resonant frequency of second section to produce a minimum signal in the first section at the centre frequency.

6. Adjust first coupling component to produce peaks in the response of the first section at the specified frequency while maintaining a minimum signal at the centre frequency (as in step 5).

7. Continue with the following procedure adjusting components further away from the input until the centre section or one section past the centre of the filter is reached. Then do step 10.

8. Remove the short circuit from the third section and adjust the resonant frequency of this section to produce a maximum signal in the first section of the centre frequency.

9. Adjust the coupling component to the third section to produce peaks at the

frequencies specified while maintaining a peak at the centre frequency (as in step 8).

10. Repeat steps 2 onwards but this time working from the output section and towards the centre of the filter using the frequencies specified under the heading "Working From Output".

11. If the coupling capacitor values are significant compared to the section resonating capacitance, it may be necessary to repeat the above adjustment procedure until consistent results can be obtained.

12. Display or measure the overall filter response and, if the passband characteristic is not satisfactory, it will be necessary to display the passband response and make minor adjustments to some components while observing the response.

APPENDIX IV

THE 10 dB BROADBAND AMPLIFIER

In both the transmitter and receiver LSG translators, the signal throughout the chain is amplified by identical 10 dB modular 50 ohm amplifiers designed to handle the frequency range of 3 to 110 MHz. This amplifier was designed with emphasis on obtaining a reasonable compromise between input and output VSWR and low intermodulation distortion.

Performance specification

Nominal power gain		10 dB
Gain variation		± 0.5 dB
3 dB bandwidth		< 1.5 MHz to > 190 MHz
Nominal input and output impedance		50
Input VSWR	< 1.5:1 < 2.0:1	2.5 MHz to 94 MHz 1.9 MHz to 150 MHz
Output VSWR	< 1.5:1 < 2.0:1	1.8 MHz to 110 MHz 3 MHz to 134 MHz
Typical 3rd order intermodulation intercept (referred to output)		+ 22 dBm
Typical two tone signal output power for 3rd order intermodulation products 70 dB down		- 13 dBm
Noise figure		Approx. 6.5 dB at 60 MHz
DC supply voltage		+ 20 V
Nominal supply current		20 Mz

See figure 88 for the circuit diagram. Figure 89 describes the typical performance of an amplifier across a wide frequency range where

$|S_{21}|$ forward power gain

$|S_{11}|$ magnitude of reflected power applied to input

$|S_{22}|$ magnitude of reflected power applied to output

$|S_{11}|$ or $|S_{22}|$ is related to reflection coefficients and VSWR by the following formulae.

$$|\rho| = 10^{\frac{|S|}{20}}$$

$$\text{VSWR} = \frac{1 + |\rho|}{1 - |\rho|}$$

where $|S|$ is $|S_{11}|$ or $|S_{22}|$ and designated the magnitude of the reflected power in dB. Note the quantity $|S|$ may be negative. $|\rho|$ is the magnitude of the reflection coefficient.

The variable capacitor in the amplifier is adjusted to obtain an input and output VSWR within specification.

TABLE 1 - RELCOM MIXER M1E INTERMODULATION PERFORMANCE

Harmonics of f_R	0	1	2	3	4	5	6	7	8
7	99	99	99	99	99	99	99	99	99
	90	90	90	90	90	90	90	90	90
6	99	99	99	97	99	99	99	99	98
	90	90	90	90	90	90	90	90	90
5	99	96	99	95	99	99	99	90	99
	90	90	90	90	90	90	90	90	90
4	88	91	99	92	90	95	87	94	87
	90	90	90	90	90	90	90	90	90
3	81	73	85	69	85	68	85	64	87
	90	90	90	90	90	90	90	89	90
2	64	71	62	70	63	70	61	62	64
	73	83	75	79	80	80	77	82	79
1	24	0	35	11	42	19	50	39	49
	24	0	34	11	42	18	49	37	49
0		29	20	32	24	29	27	30	29
		18	10	23	14	19	17	21	19

Harmonics of f_L

(Mixing products are indicated by the number of dB below the $f_L \pm f_R$ output)

TABLE 2 - INTERFERENCE LEVELS - TRANSMITTER FIRST MIXER STAGE

Harmonic Number	Local Oscillator Harmonics	Power levels from M9E (down on IF output levels $f_L \pm f_R$)	$nf_{LO} \pm f_R$ (f_R = 1.0 - 1.5 MHz)		Power levels from M1E (down on IF output levels $f_L \pm f_R$)
1	4.8	18.0	5.8 - 6.3	3.8 - 3.3	-
2	9.6	10.0	10.6 - 11.1	8.3 - 7.8	34
3	14.4	23.0	15.4 - 15.9	12.8 - 12.3	11
4	19.2	14.0	20.2 - 20.7	17.3 - 16.8	42
5	24.0	19.0	25.0 - 25.5	21.8 - 21.3	18
6	28.8	17.0	29.8 - 30.3	26.3 - 25.8	49
7	33.6	21.0	34.6 - 35.1	30.8 - 30.3	37
8	38.4	19.0	39.4 - 39.9	35.3 - 34.8	49
9	43.2	21.0*	44.2 - 44.7	39.8 - 39.3	50*
10	48.0	21.0*	49.0 - 49.5	44.3 - 43.8	50*

*Estimated

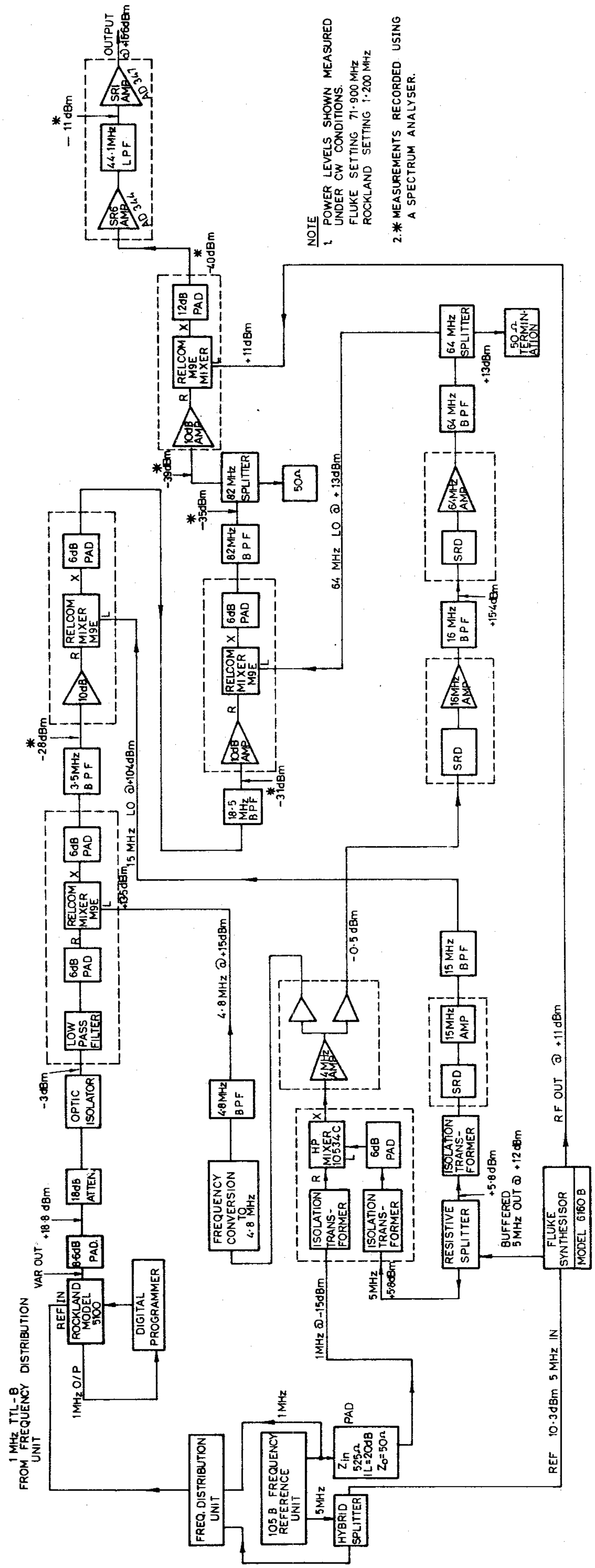


Figure 1. Block diagram : Transmitter translation chain

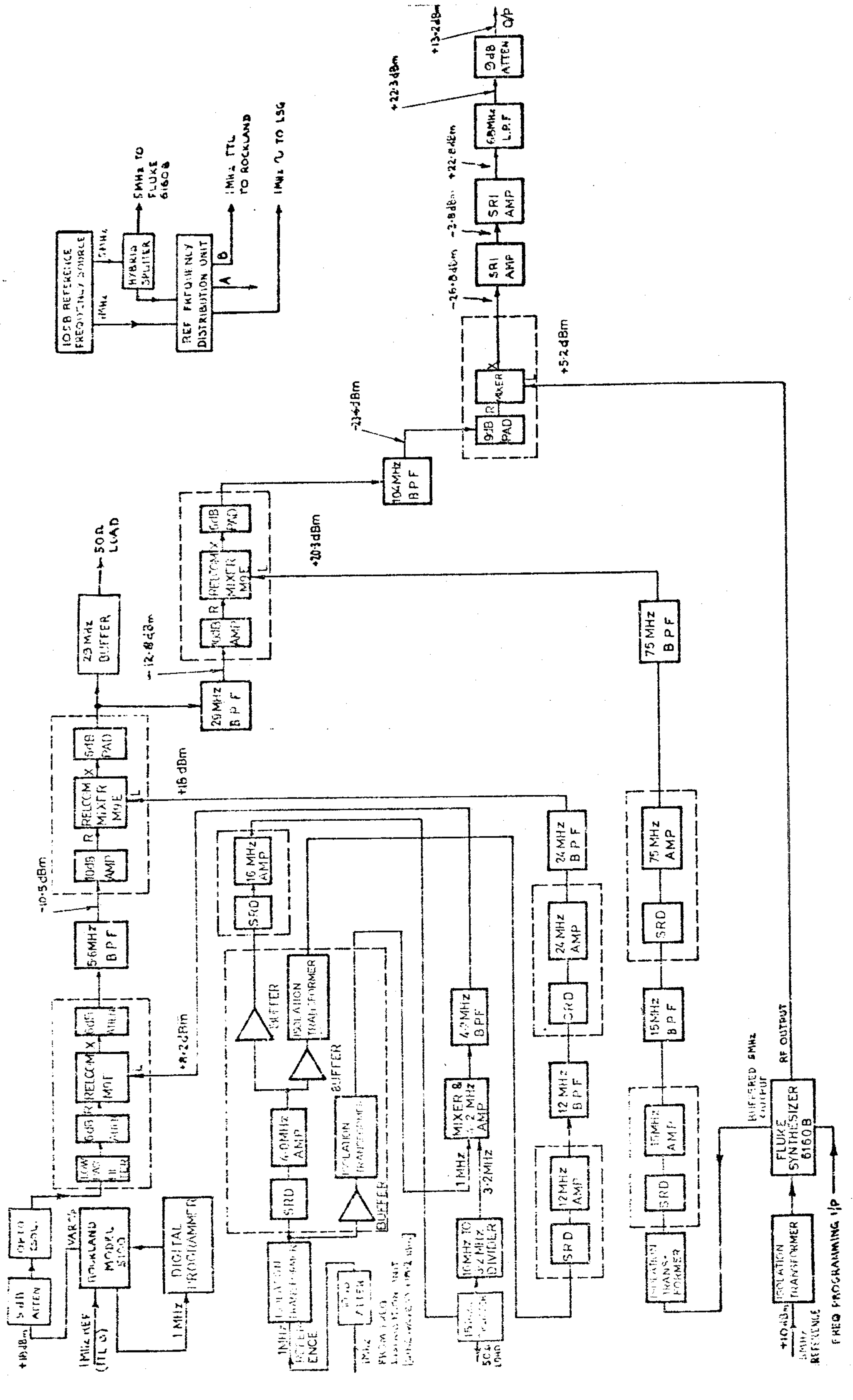


Figure 2. Block diagram : Receiver translation chain

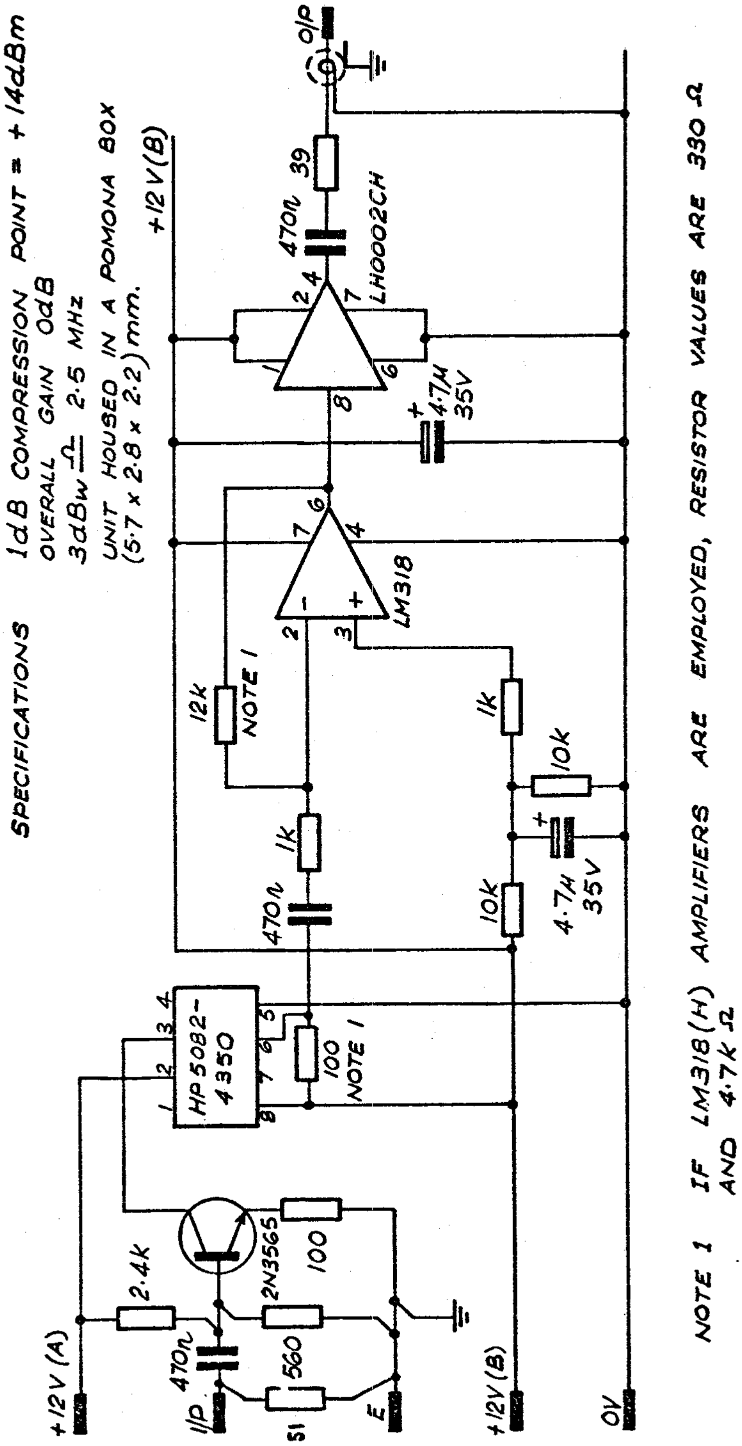


Figure 3. Electro optic coupled isolator

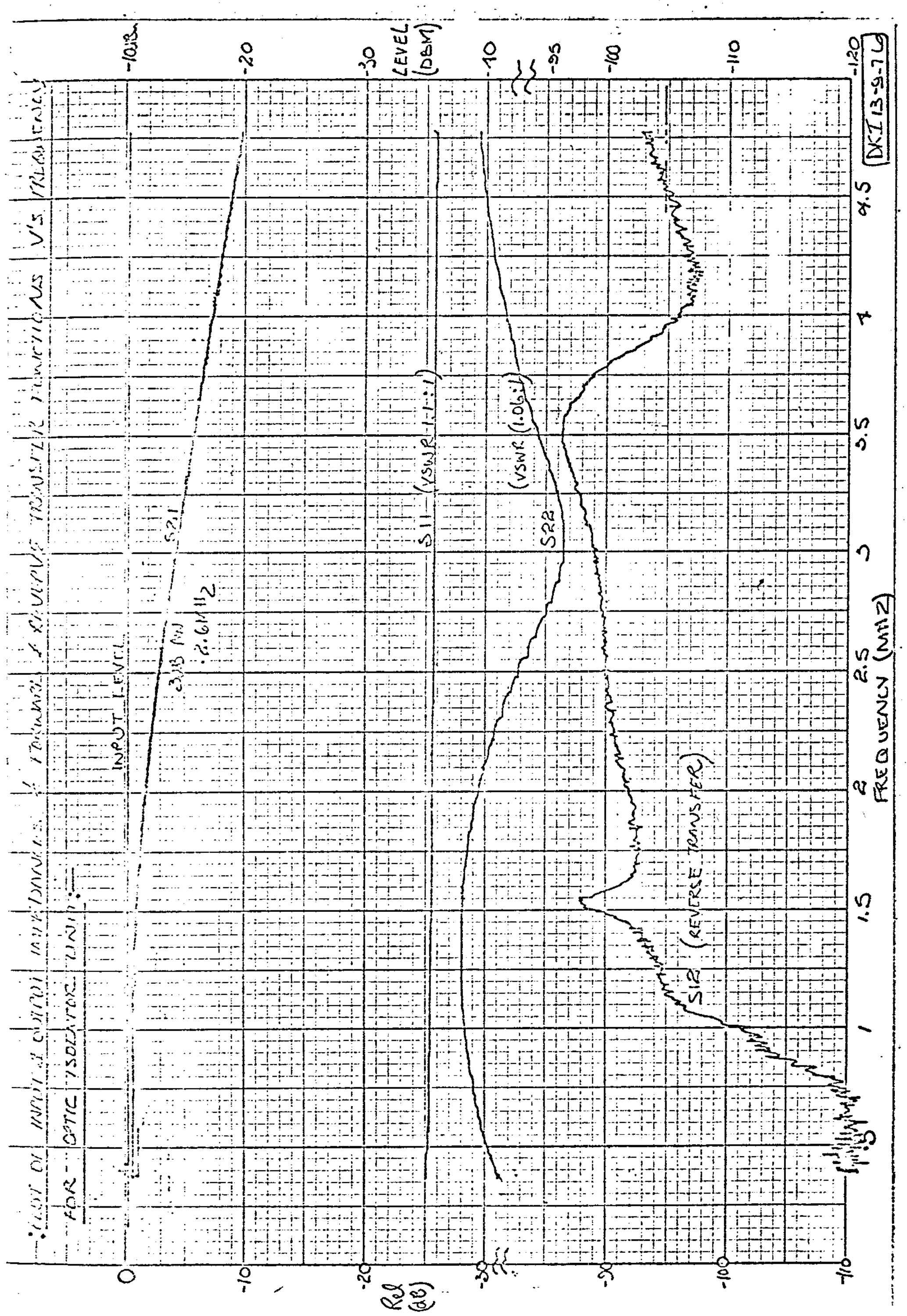


Figure 4. S parameters versus frequency - electro optic isolator

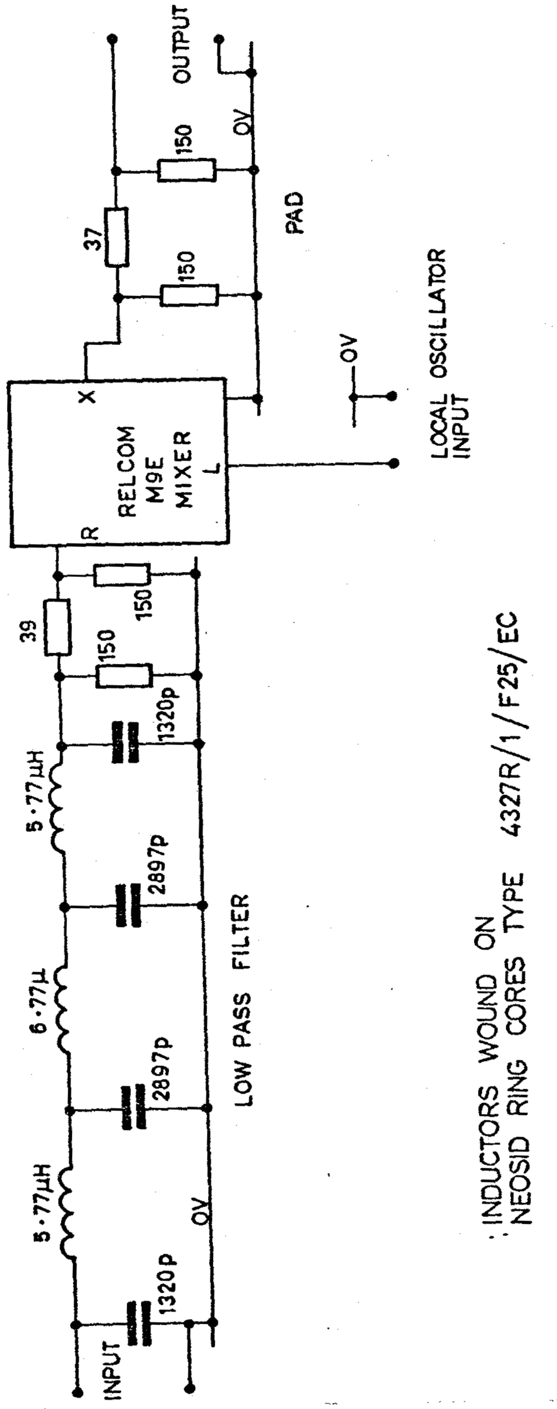


Figure 5. Low pass filter and first mixer stage (transmitter)

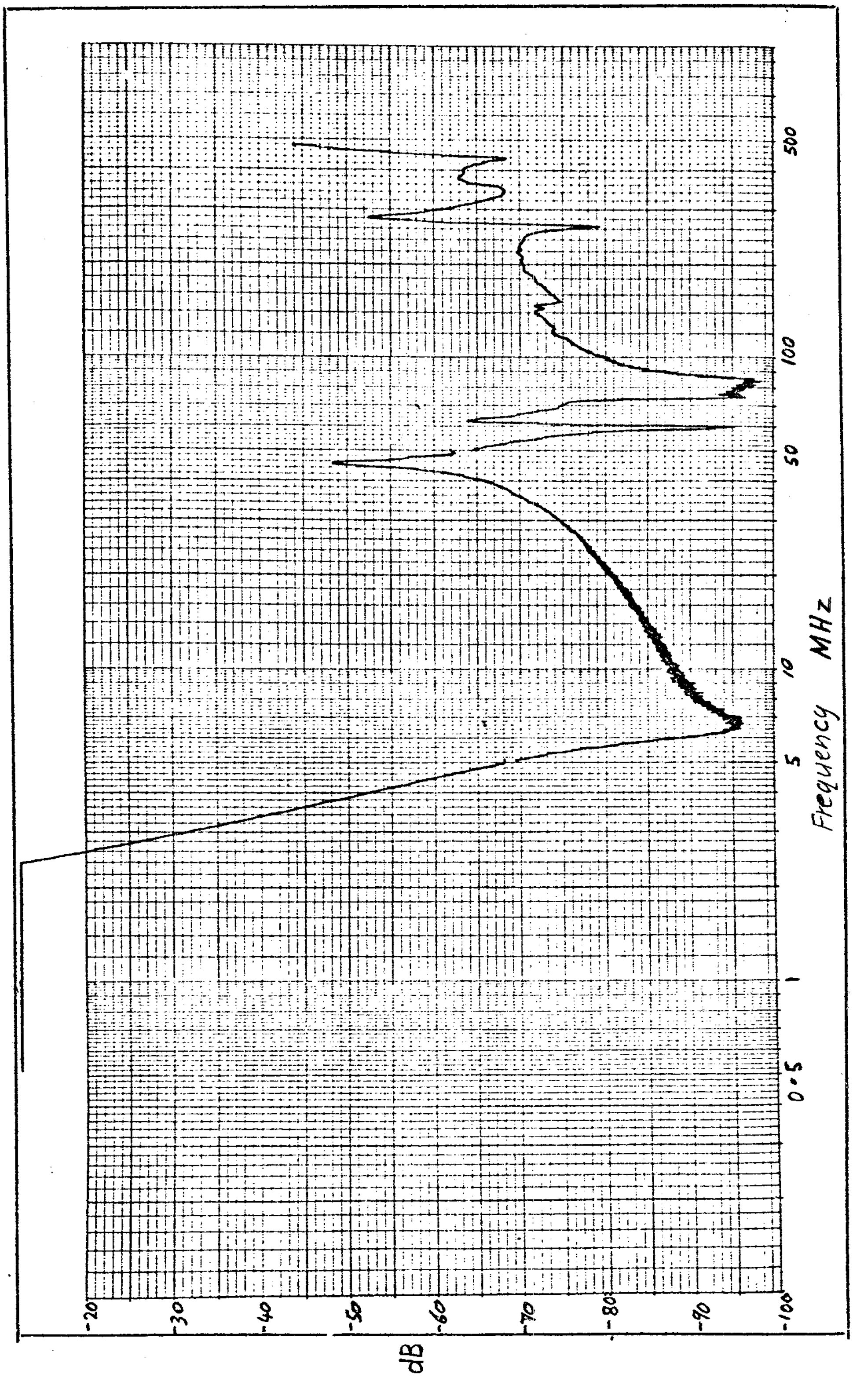
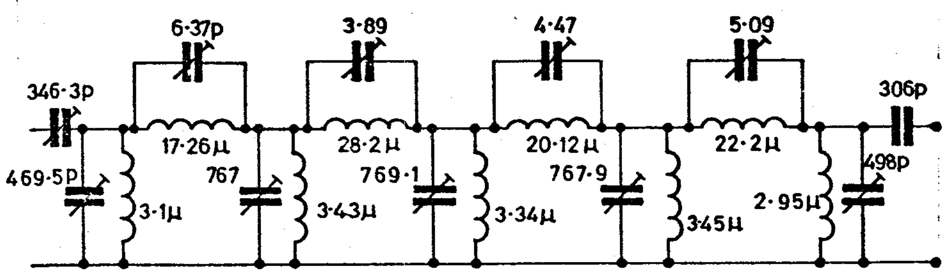


Figure 6. Measured 2.2 MHz low pass filter - insertion loss



<u>FILTER DESIGN DATA:</u> CHEBYSHEV 0.1dB RIPPLE RESPONSE
CENTRE FREQUENCY = 3.54 MHz
BANDWIDTH = 0.68 MHz
MATCHED TO 50Ω AT INPUT AND OUTPUT
UNLOADED INDUCTOR Q = 200

ALIGNMENT OF FILTER
FOR METHOD SEE SECTION 9.4 ZVEREV "HANDBOOK OF FILTER SYNTHESIS"

SECTION	WIDTH (MHz)	LOWER FREQ. (MHz)	UPPER FREQ. (MHz)
WORKING FROM INPUT			
BW OF 1ST	0.54478	3.26761	3.81239
BTWN PEAKS 2ND	0.50429	3.28786	3.79214
OUTER PEAKS 3RD	0.59150	3.24425	3.83575
INNER PEAKS 4TH	0.33725	3.37137	3.70863
OUTER PEAKS 4TH	0.65360	3.21320	3.86680
WORKING FROM OUTPUT			
BW OF 1ST	0.44044	3.31978	3.76022
BTWN PEAKS 2ND	0.39236	3.34382	3.73618
OUTER PEAKS 3RD	0.58737	3.24631	3.83369
INNER PEAKS 4TH	0.19078	3.44461	3.63539
OUTER PEAKS 4TH	0.63574	3.22213	3.85787

Figure 7. 3.55 MHz band pass filter

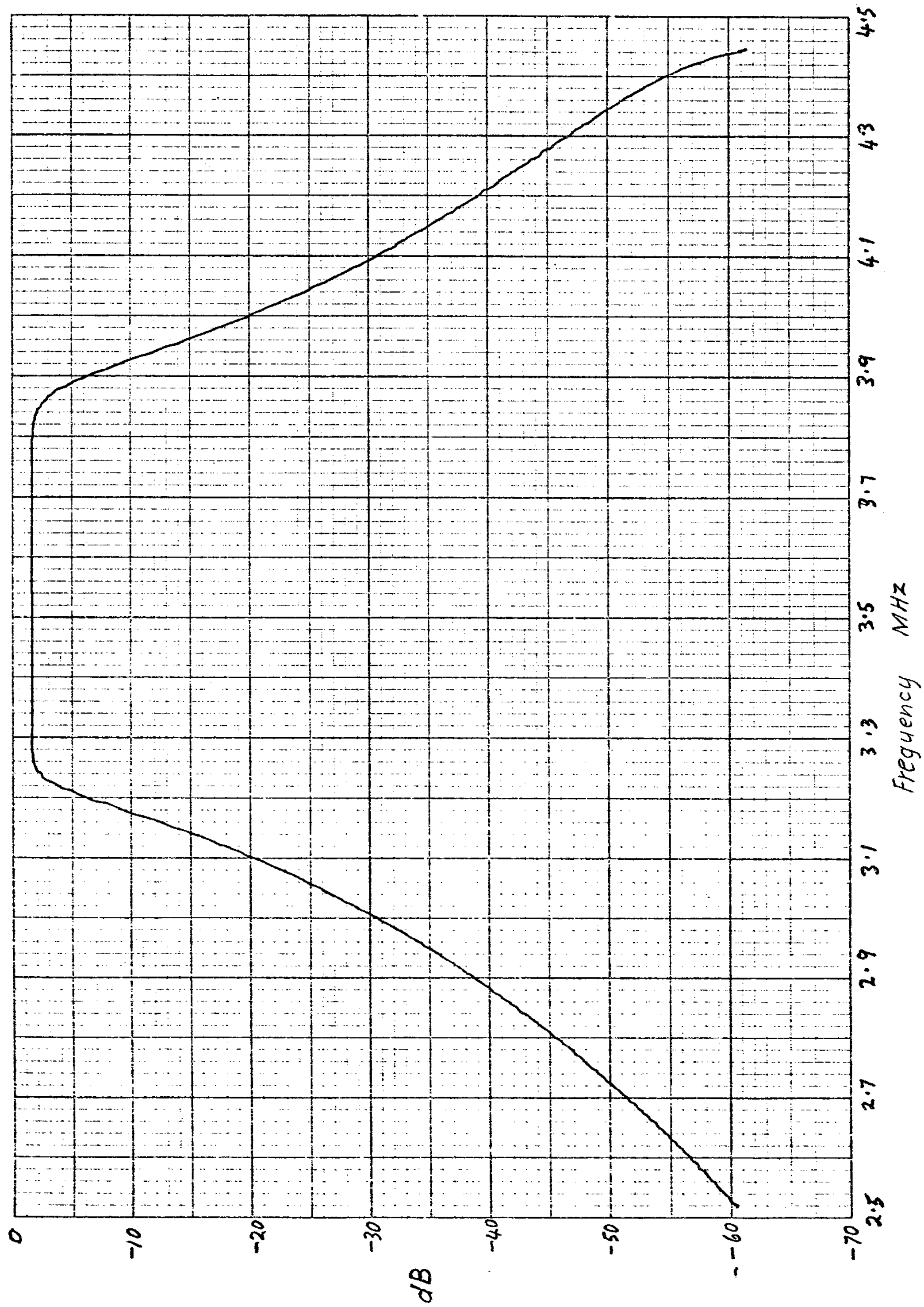


Figure 8. Measured 3.55 MHz band pass filter insertion loss (transmitter signal chain)

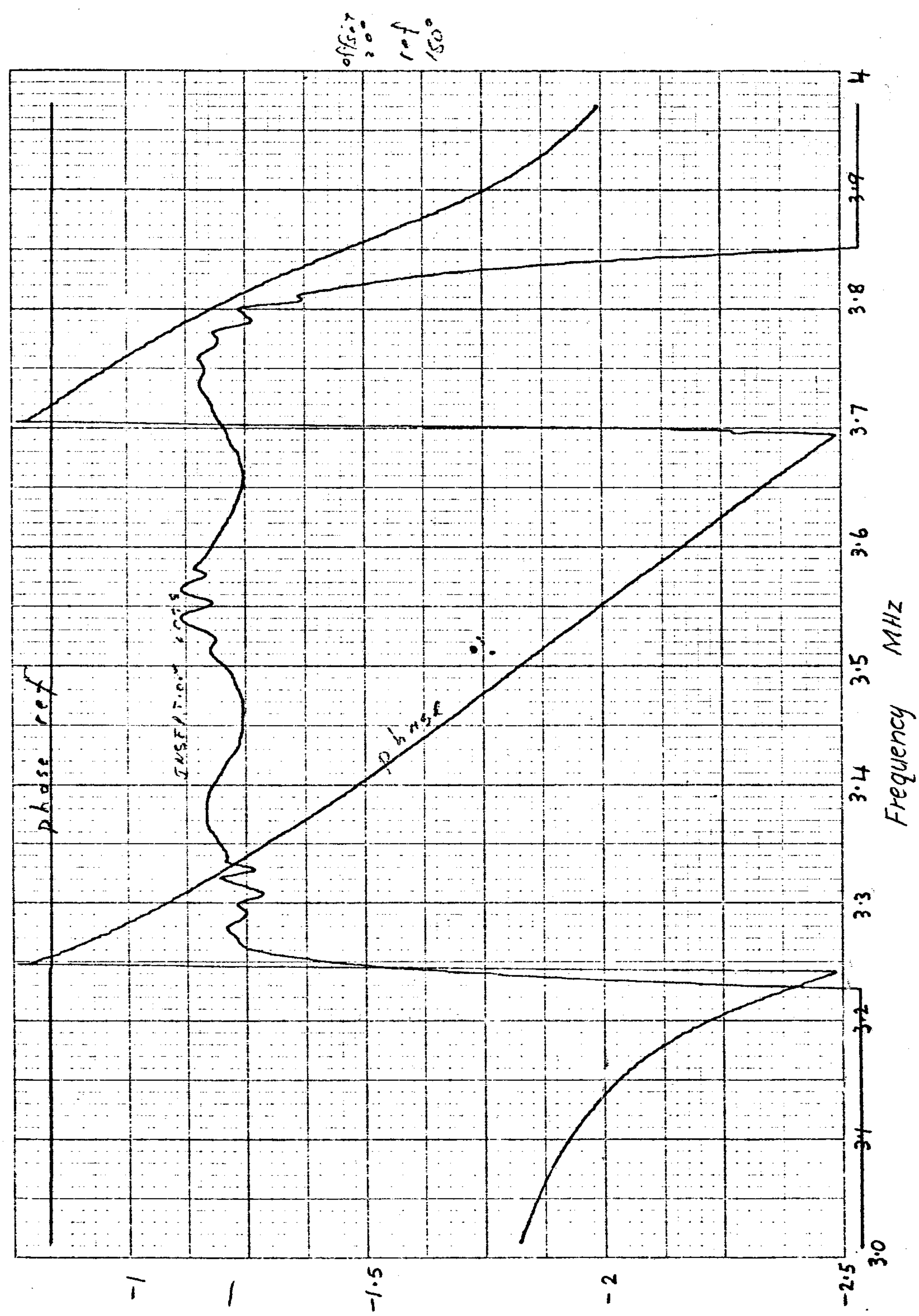


Figure 9. Measured 3.55 MHz band pass filter insertion loss and phase about centre frequency (transmitter signal chain)

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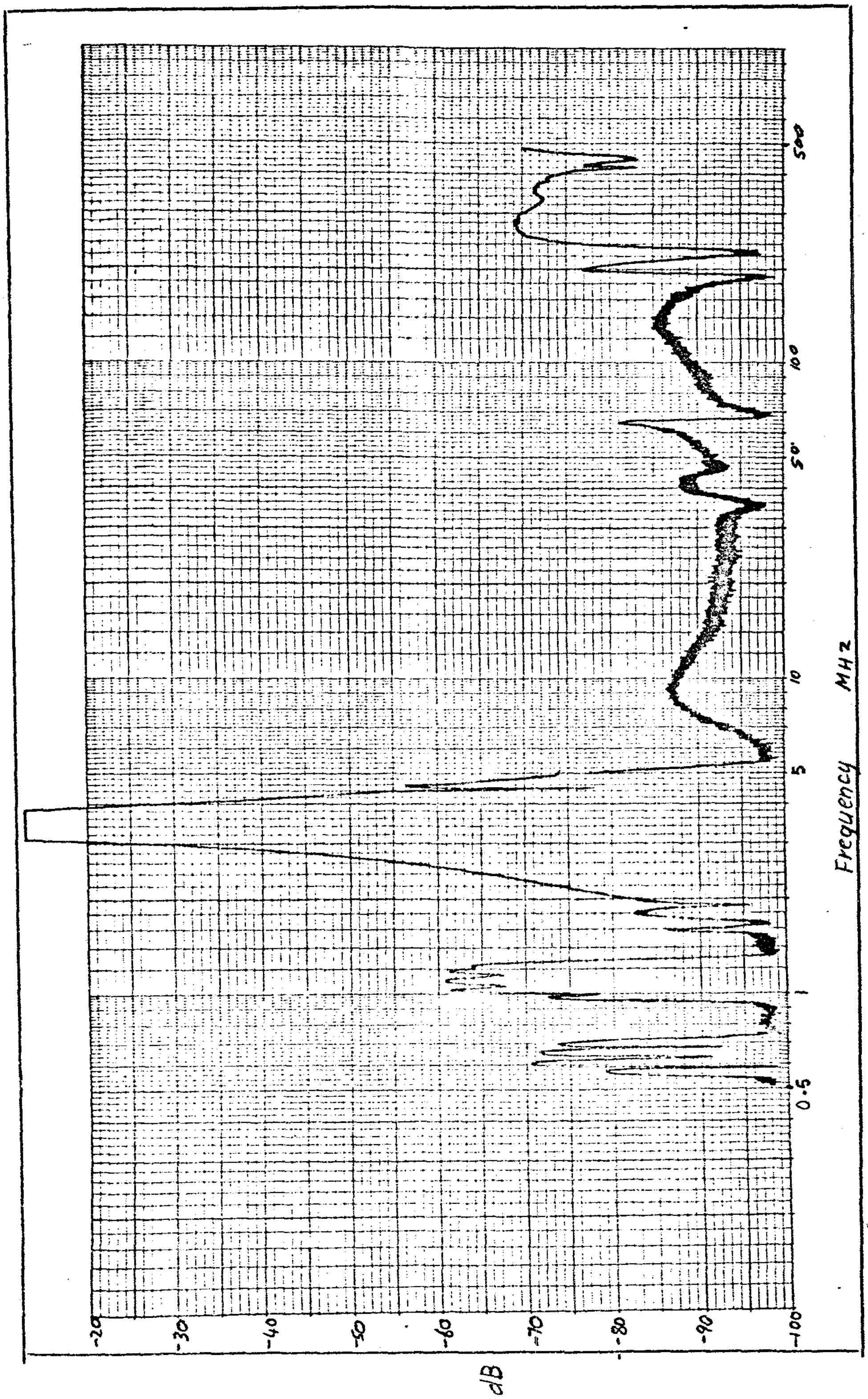

Figure 10. Measured 3.55 MHz band pass filter insertion loss from 0.5 to 500 MHz (transmitter signal chain)

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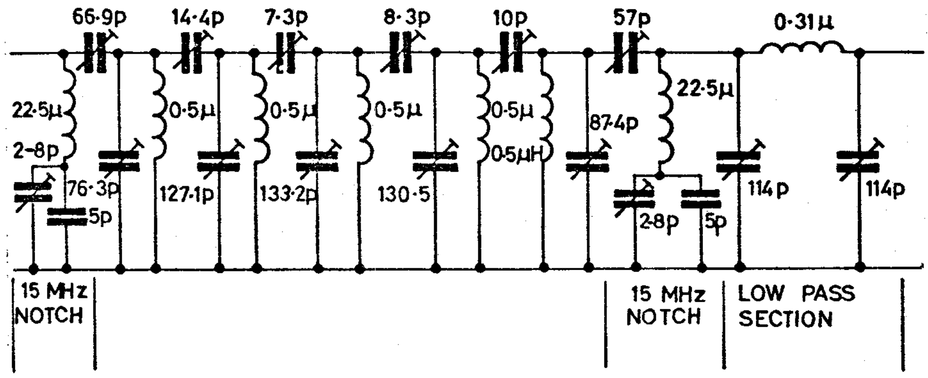


FILTER DESIGN DATA: BUTTERWORTH RESPONSE
CENTRE FREQUENCY = 18.45 MHz
BANDWIDTH = 1.67 MHz
UNLOADED INDUCTOR Q = 190
MATCHED TO 50 Ω INPUT AND OUTPUT
LOW PASS SECTION CUTOFF = 40 MHz

ALIGNMENT OF FILTER
FOR METHOD SEE SECTION 9.4 ZVEREV "HANDBOOK OF FILTER SYNTHESIS"

SECTION	WIDTH(MHz)	LOWER FREQ.(MHz)	UPPER FREQ.(MHz)
WORKING FROM INPUT			
BW OF 1ST	2.89077	16.96961	19.86037
BTWN PEAKS 2ND	1.78874	17.52062	19.30936
OUTER PEAKS 3RD	2.00380	17.41309	19.41689
INNER PEAKS 4TH	0.88915	17.97042	18.85956
OUTER PEAKS 4TH	2.06952	17.38024	19.44976
WORKING FROM OUTPUT			
BW OF 1ST	2.20404	17.31298	19.51700
BTWN PEAKS 2ND	1.24448	17.79274	19.03724
OUTER PEAKS 3RD	1.61462	17.60768	19.22229
INNER PEAKS 4TH	0.64871	18.09064	18.73934
OUTER PEAKS 4TH	1.73258	17.38024	19.28128

Figure 11. 18.45 MHz band pass filter

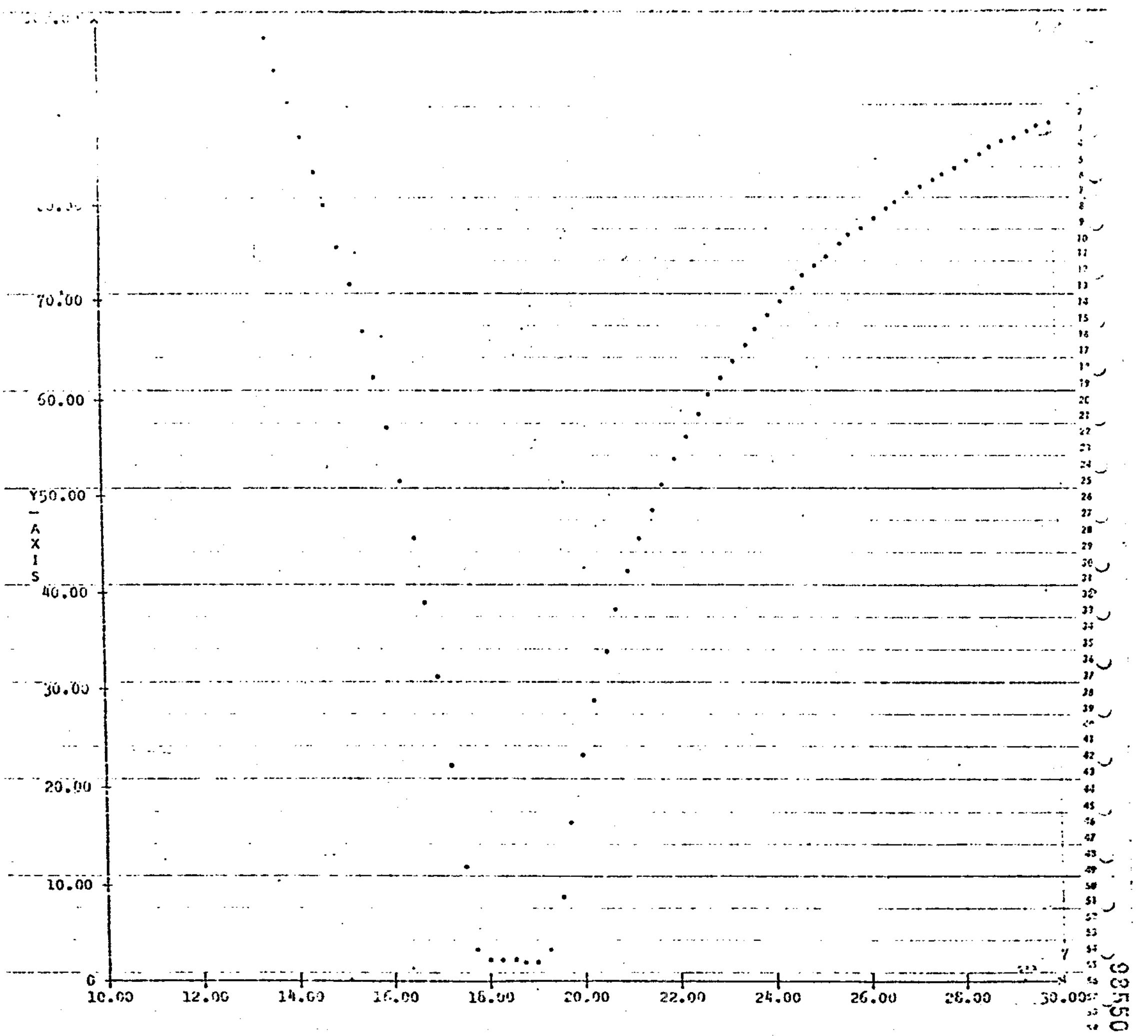


Figure 12. Computer 18.45 MHz band pass filter insertion loss

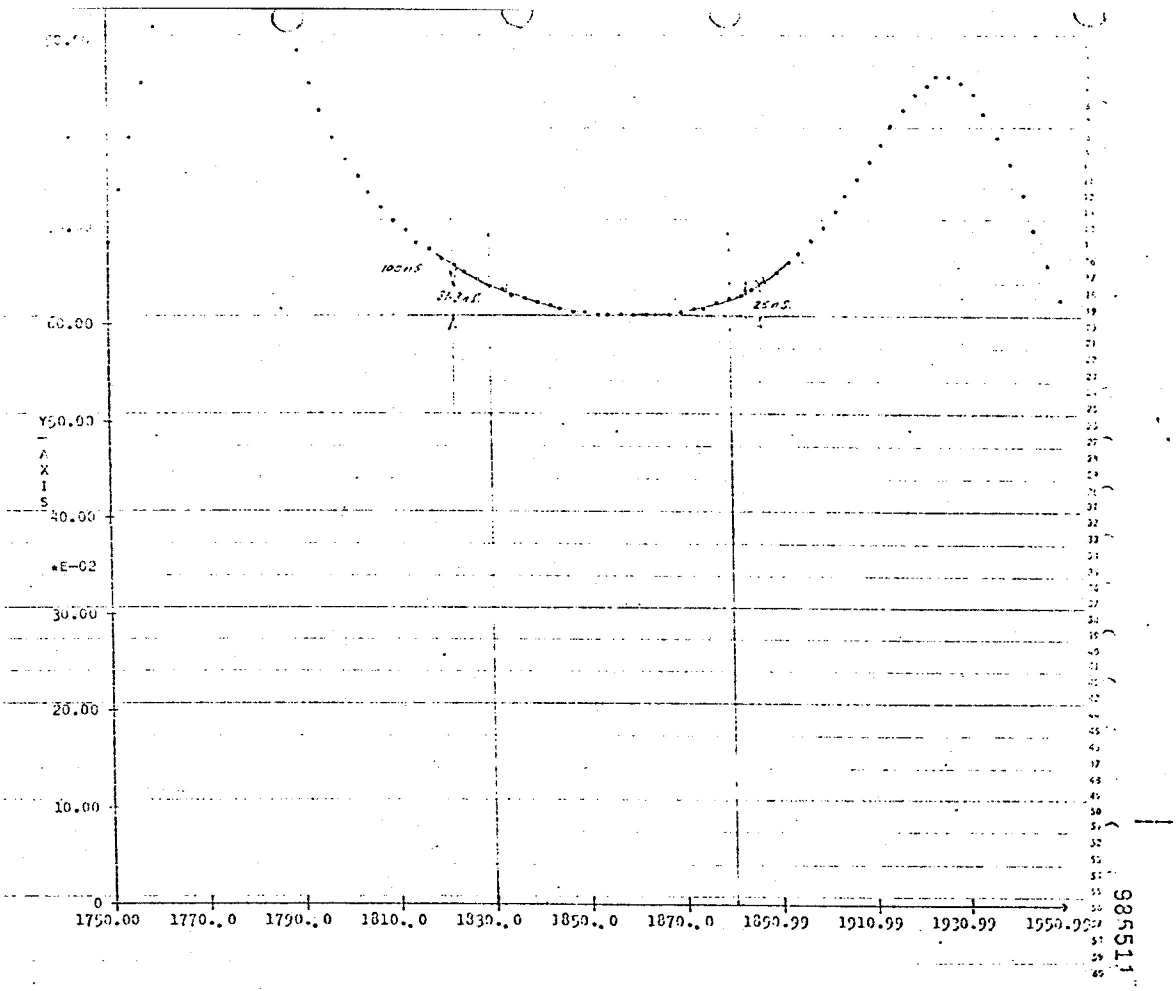


Figure 13. Computed group delay 18.45 MHz band pass filter

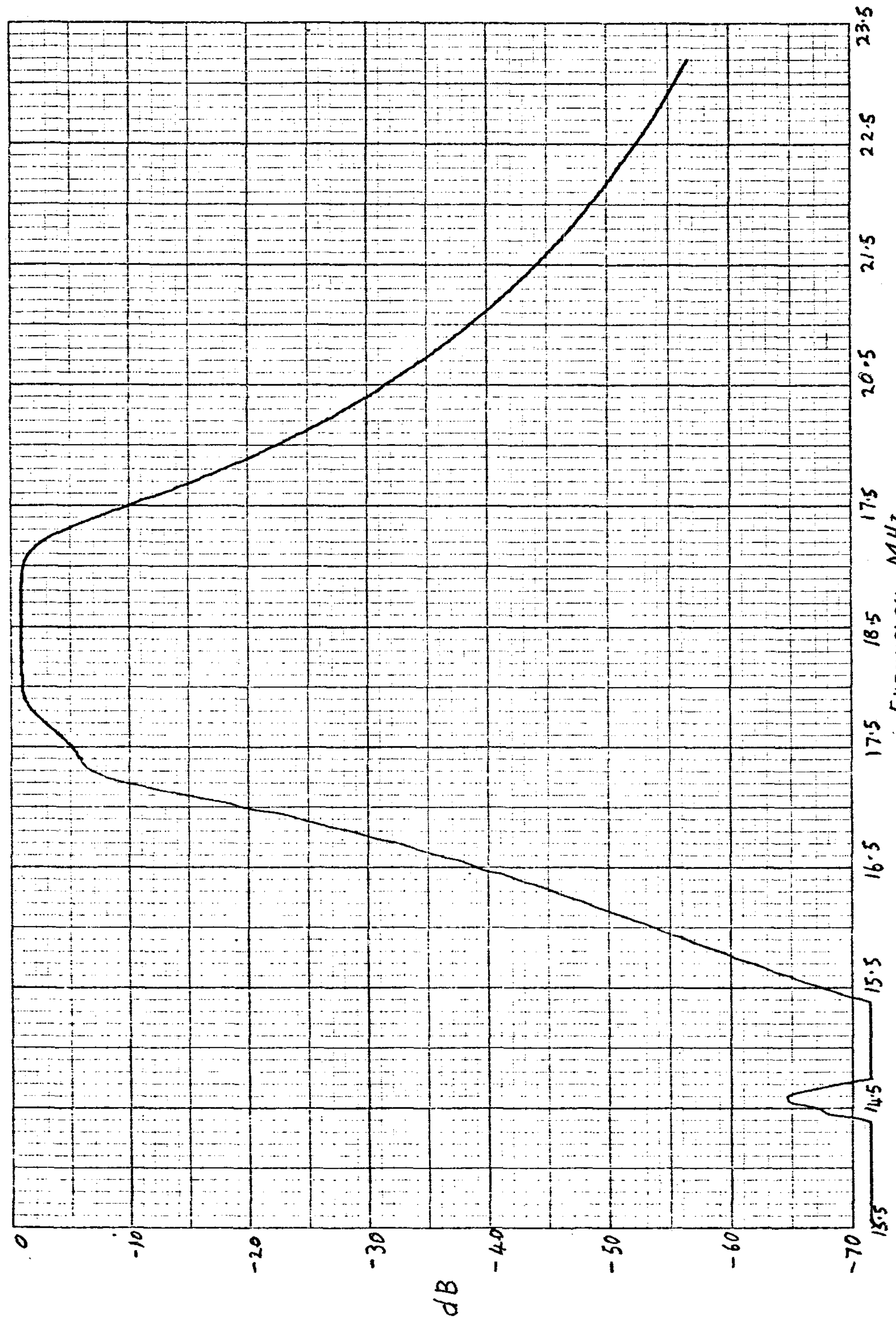


Figure 14. Measured 18.45 MHz band pass filter insertion loss (transmitter signal chain)

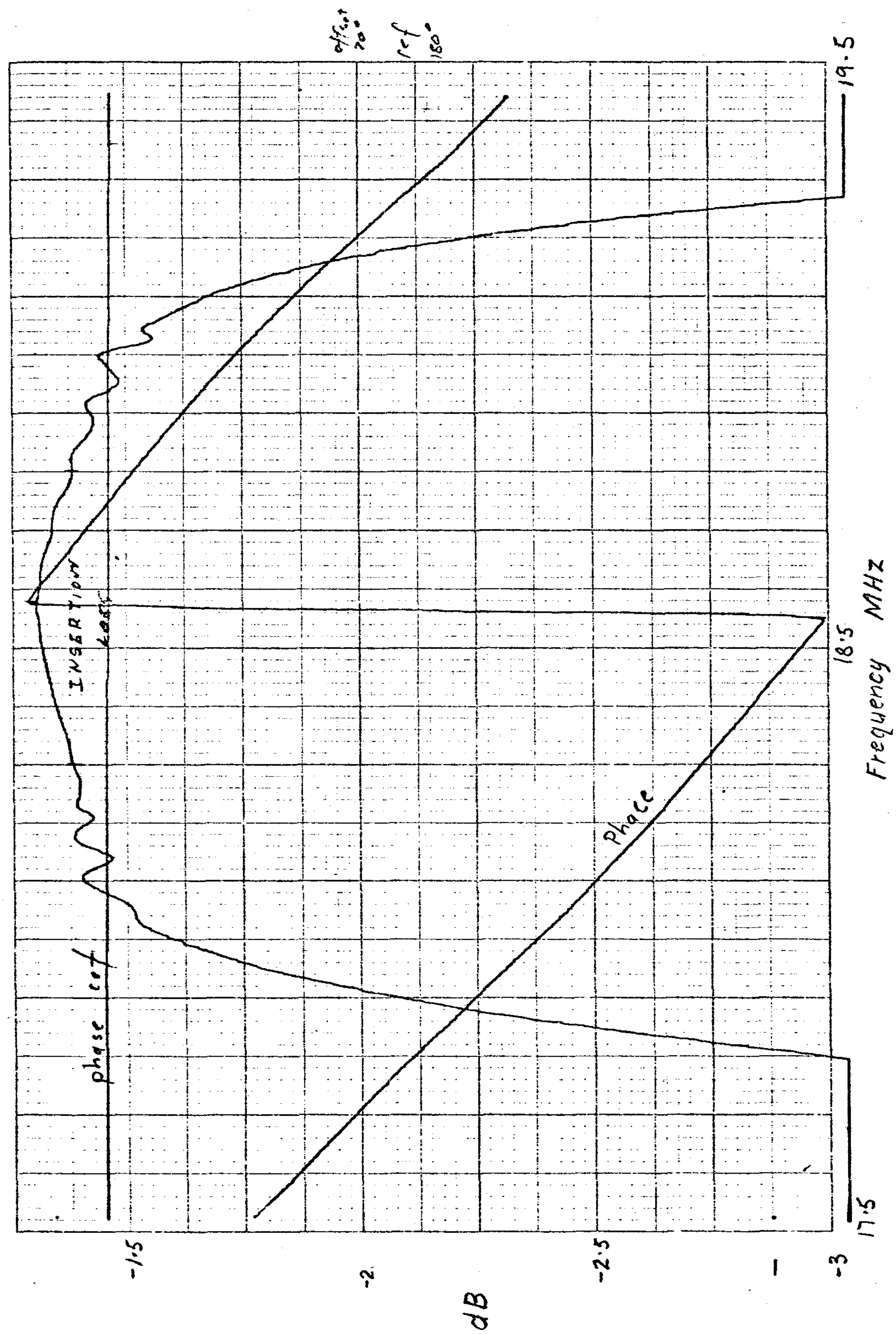


Figure 15. Measured 18.45 MHz band pass filter insertion loss and phase about centre frequency (transmitter)

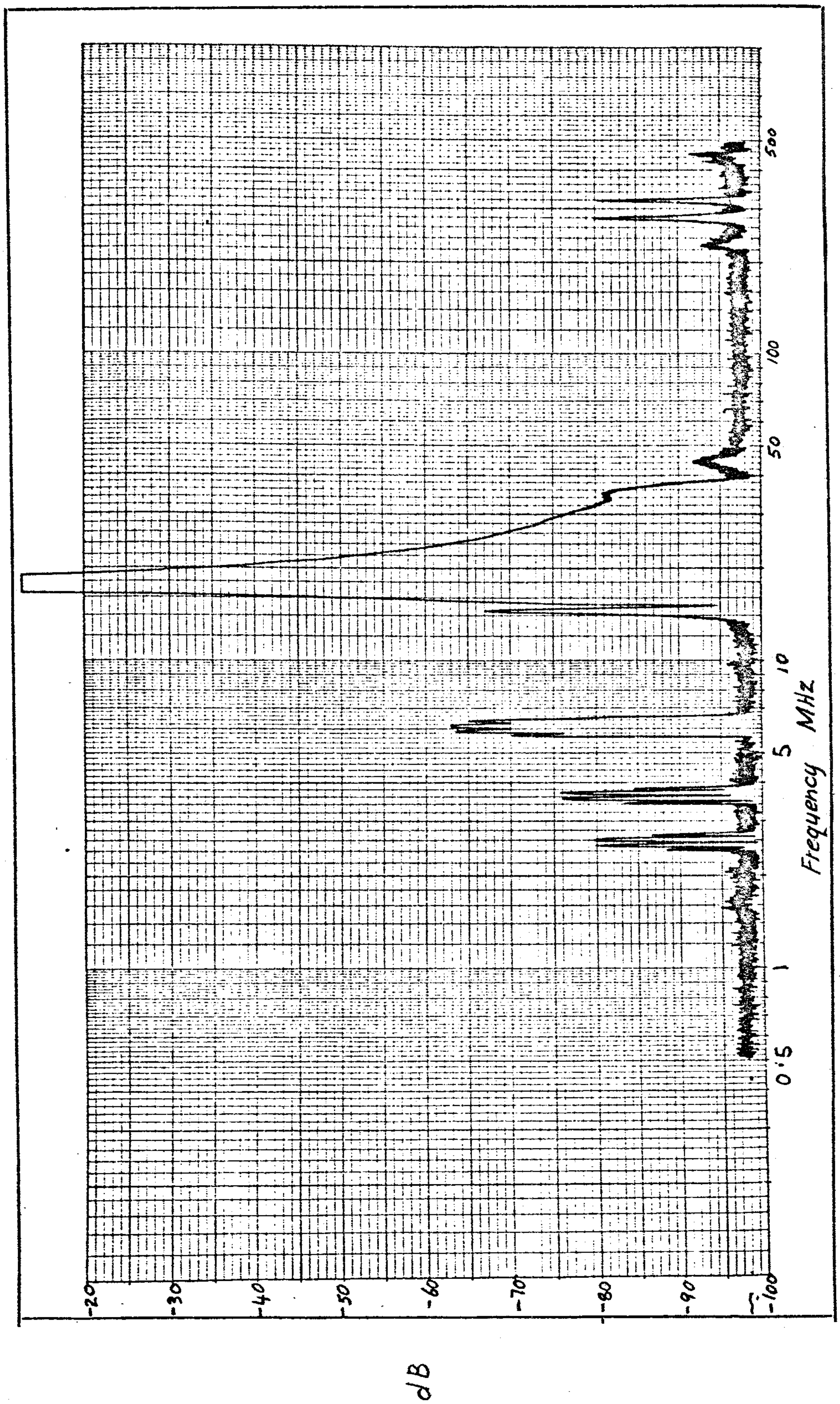
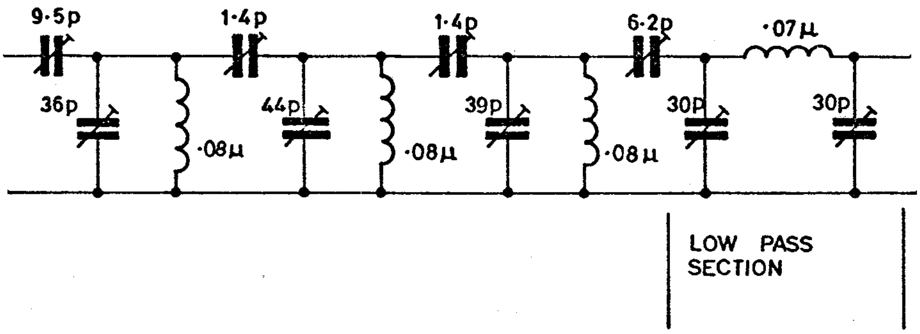


Figure 16. Measured 18.45 MHz band pass filter insertion loss from 0.5 to 500 MHz (transmitter signal chain)



FILTER DESIGN DATA: BUTTERWORTH RESPONSE
CENTRE FREQUENCY = 82.5 MHz
BANDWIDTH = 3.5 MHz
UNLOADED INDUCTOR Q = 200
MATCHED TO 50 Ω AT INPUT AND OUTPUT
LOW PASS SECTION CUTOFF = 150 MHz

ALIGNMENT OF FILTER
FOR METHOD SEE SECTION 9.4 ZVEREV "HANDBOOK OF FILTER SYNTHESIS"

SECTION	WIDTH (MHz)	LOWER FREQ. (MHz)	UPPER FREQ. (MHz)
WORKING FROM INPUT			
BW OF 1ST	4.32793	80.33603	84.66396
BTWN PEAKS 2ND	2.45175	81.27412	83.72586
OUTER PEAKS 3RD	3.43626	80.78186	84.21812
WORKING FROM OUTPUT			
BW OF 1ST	2.14711	81.42644	83.57355
BTWN PEAKS 2ND	2.40765	81.29617	83.70381
OUTER PEAKS 3RD	3.43626	80.78186	84.21812

Figure 17. 82.5 MHz band pass filter

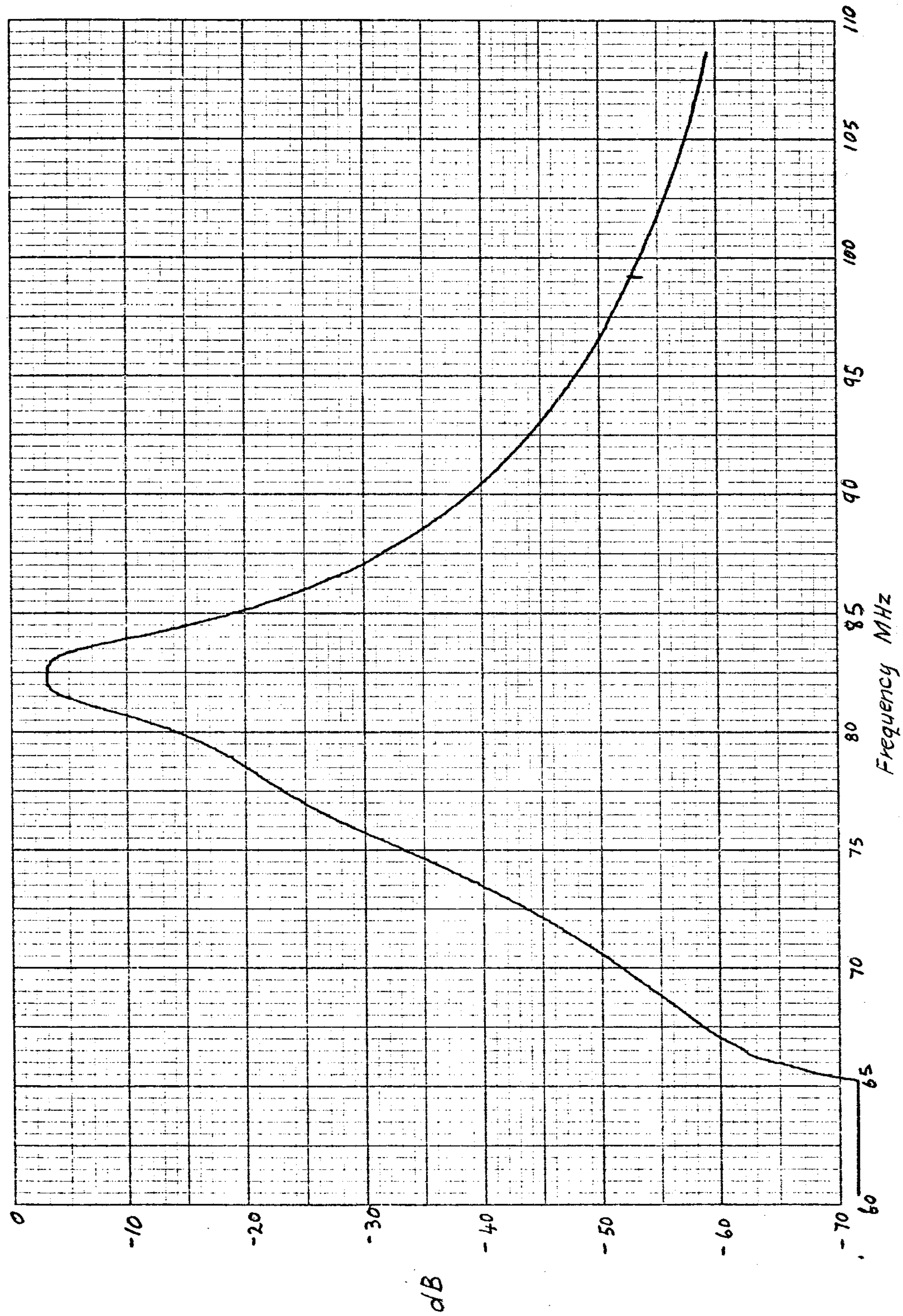


Figure 18. Measured 82.5 MHz band pass filter insertion loss (transmitter signal chain)

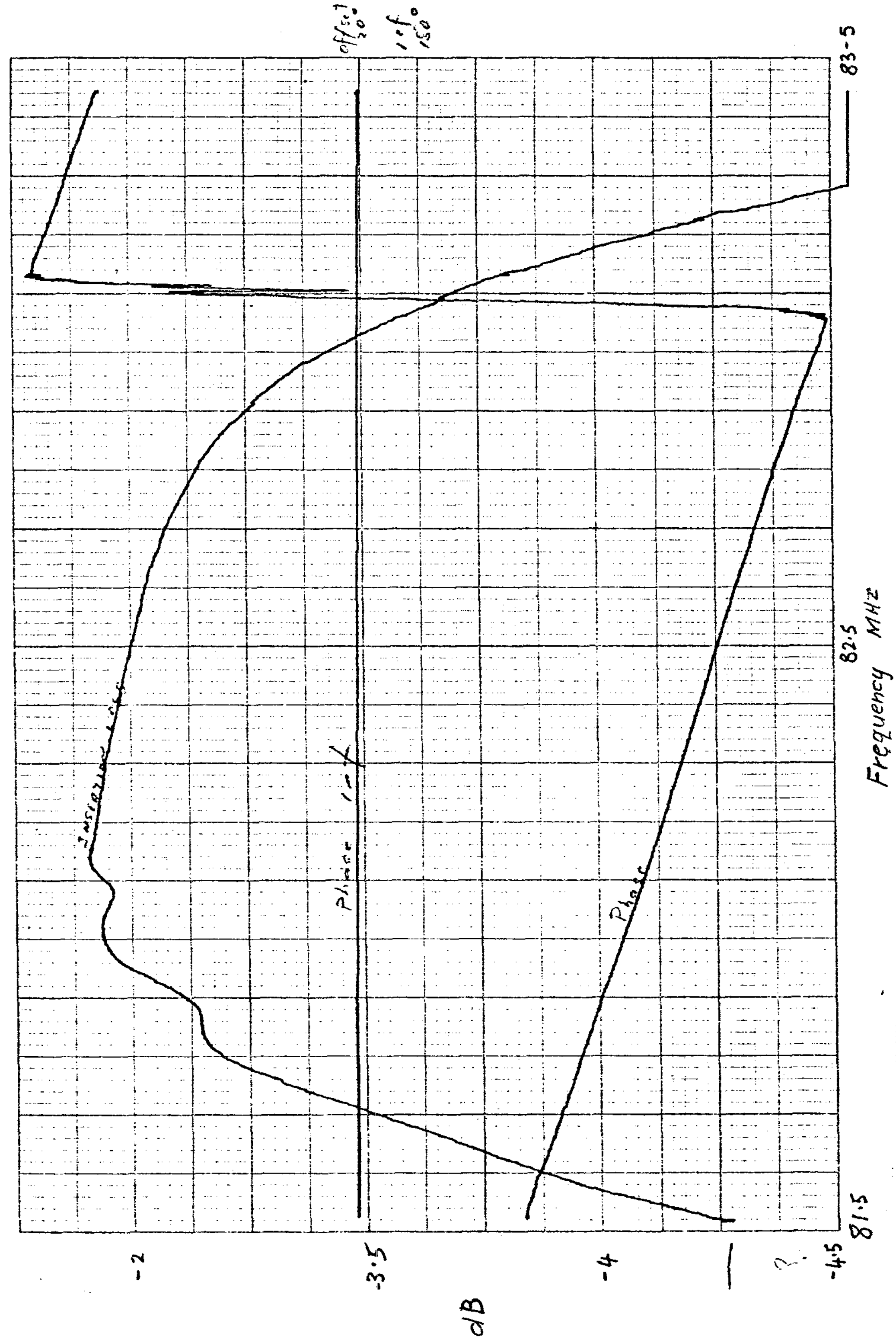


Figure 19. Measured 82.5 MHz band pass filter insertion loss
(transmitter signal chain)

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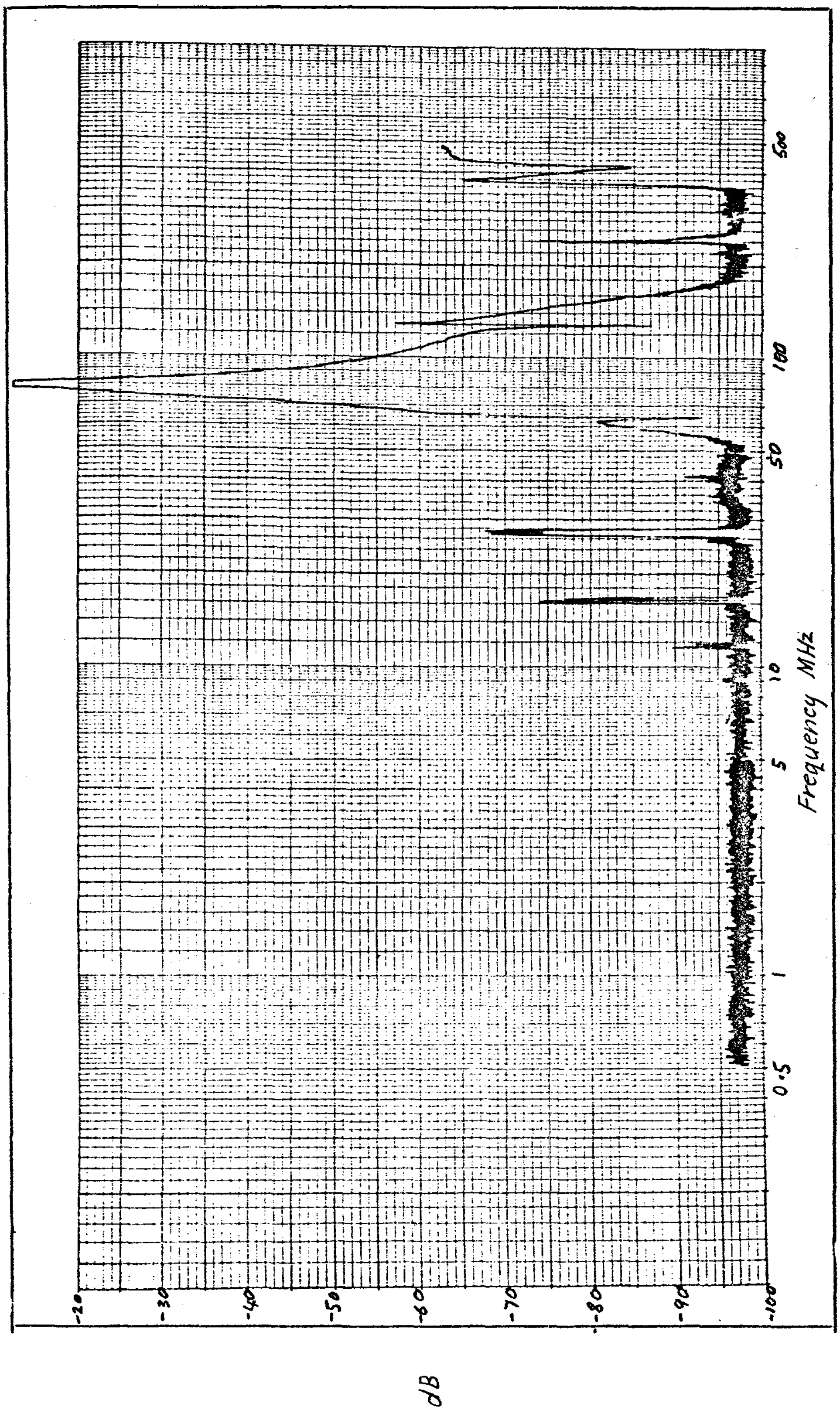

Figure 20. Measured 82.45 MHz band pass filter insertion loss from 0.5 to 500 MHz (transmitter)

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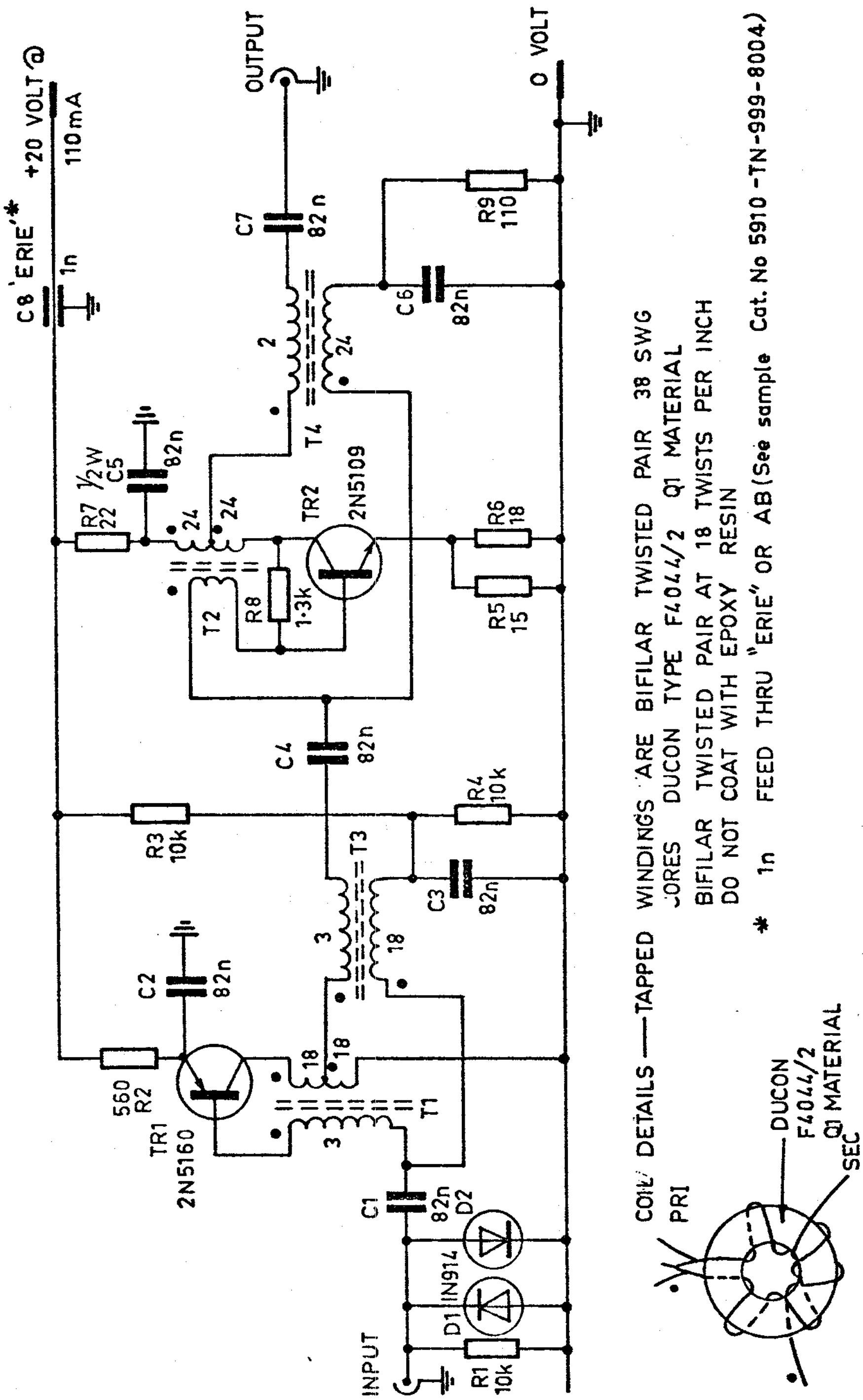


Figure 21. Broad band RF amplifier

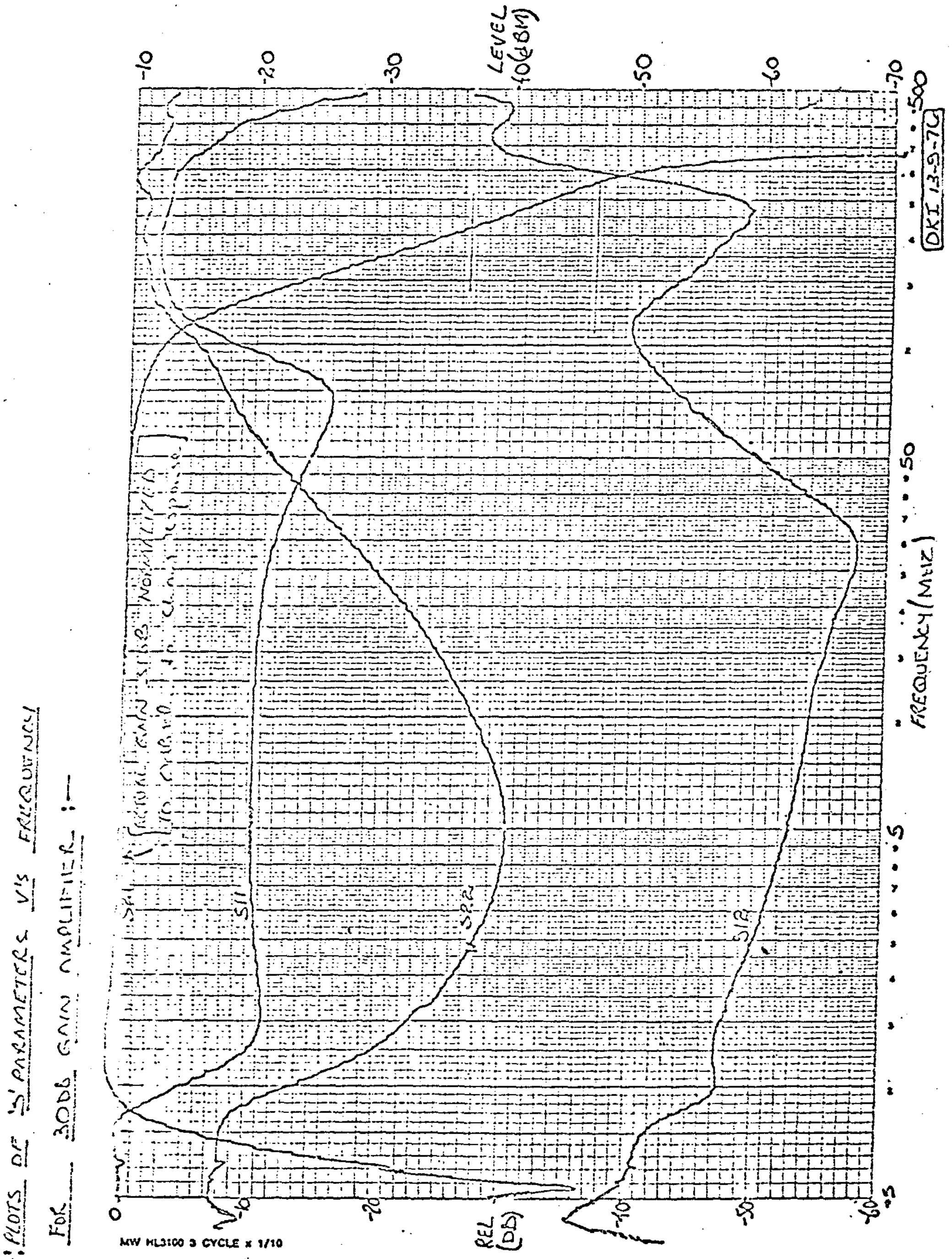


Figure 22. S parameters versus frequency for broad band amplifier

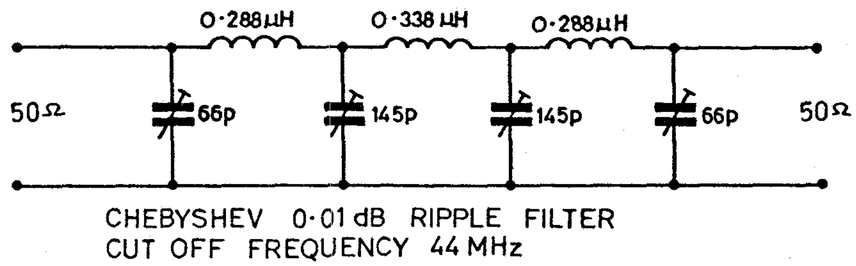


Figure 23. 44 MHz low pass filter at the output of the transmitter chain

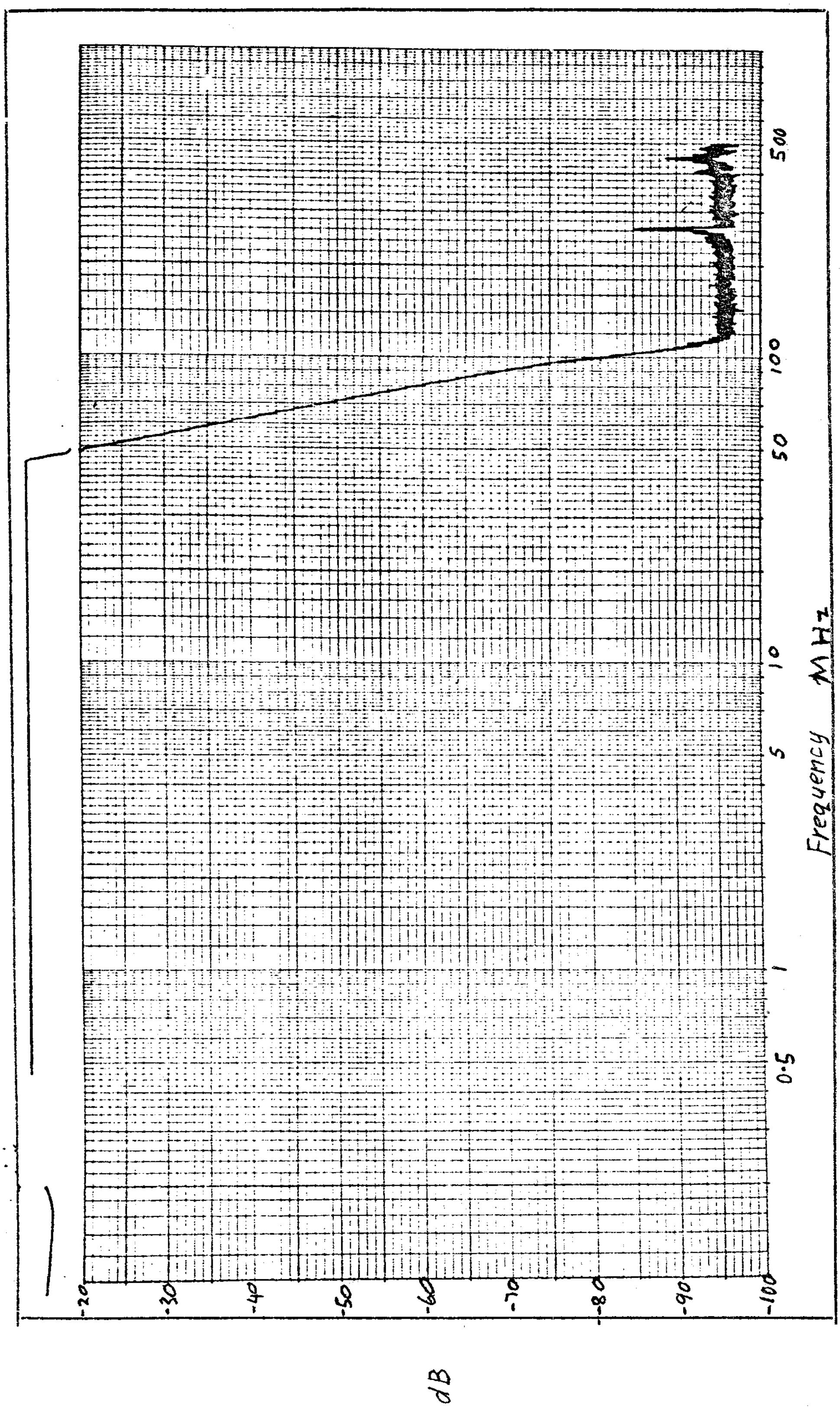
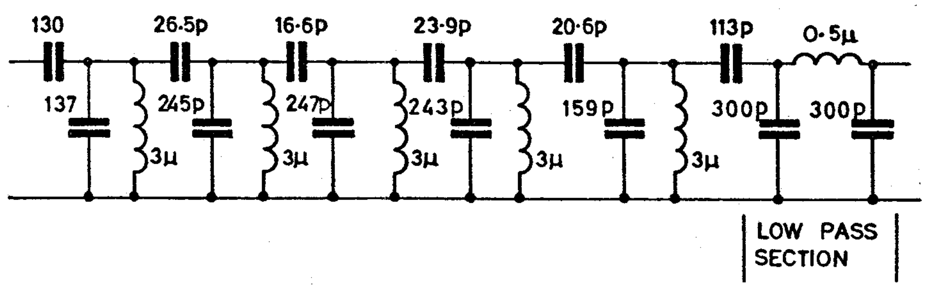


Figure 24. Measured 44.1 MHz low pass filter insertion loss from 0.5 to 500 MHz (transmitter)



FILTER DESIGN DATA:

LEGENDRE RESPONSE
CENTRE FREQUENCY = 5.415 MHz
BANDWIDTH = 0.68 MHz
UNLOADED INDUCTOR Q = 200
MATCHED TO 50Ω AT INPUT AND OUTPUT
LOW PASS SECTION CUTOFF = 20 MHz

ALIGNMENT OF FILTER
FOR METHOD SEE SECTION 9.4 ZVEREV "HANDBOOK OF FILTER SYNTHESIS"

SECTION	WIDTH(MHz)	LOWER FREQ.(MHz)	UPPER FREQ.(MHz)
WORKING FROM INPUT			
BW OF 1ST	0.54119	5.14441	5.68559
BTWN PEAKS 2ND	0.49837	5.16581	5.66419
OUTER PEAKS 3RD	0.58804	5.12098	5.70902
INNER PEAKS 4TH	0.34107	5.24446	5.58554
OUTER PEAKS 4TH	0.65698	5.08651	5.74349
WORKING FROM OUTPUT			
BW OF 1ST	0.41986	5.20507	5.62493
BTWN PEAKS 2ND	0.38787	5.22106	5.60894
OUTER PEAKS 3RD	0.59380	5.11810	5.71190
INNER PEAKS 4TH	0.18800	5.32100	5.50900
OUTER PEAKS 4TH	0.64395	5.09302	5.73698

Figure 25. 5.4 MHz band pass filter

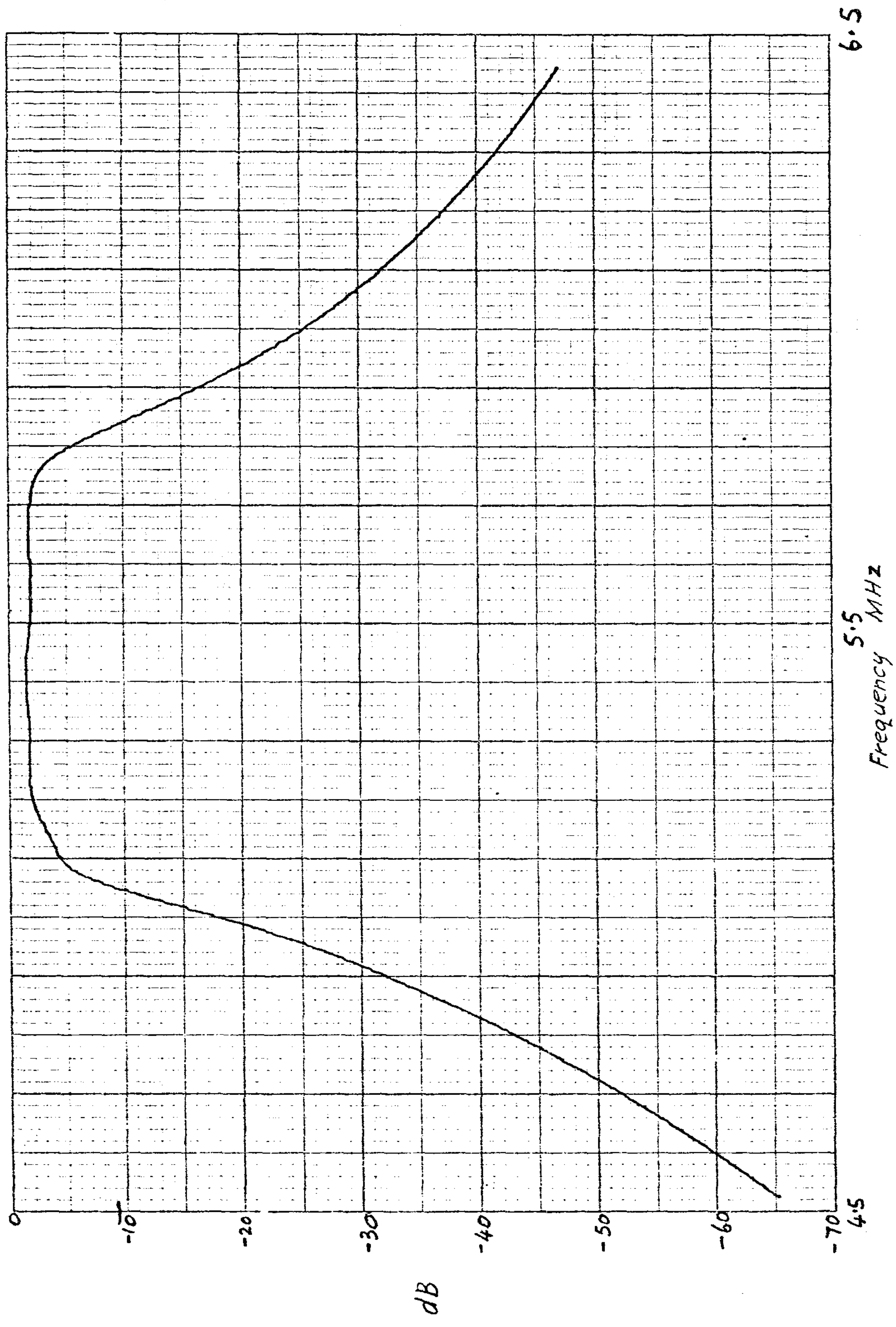


Figure 26. Measured 5.45 MHz band pass filter insertion loss (receiver signal chain)

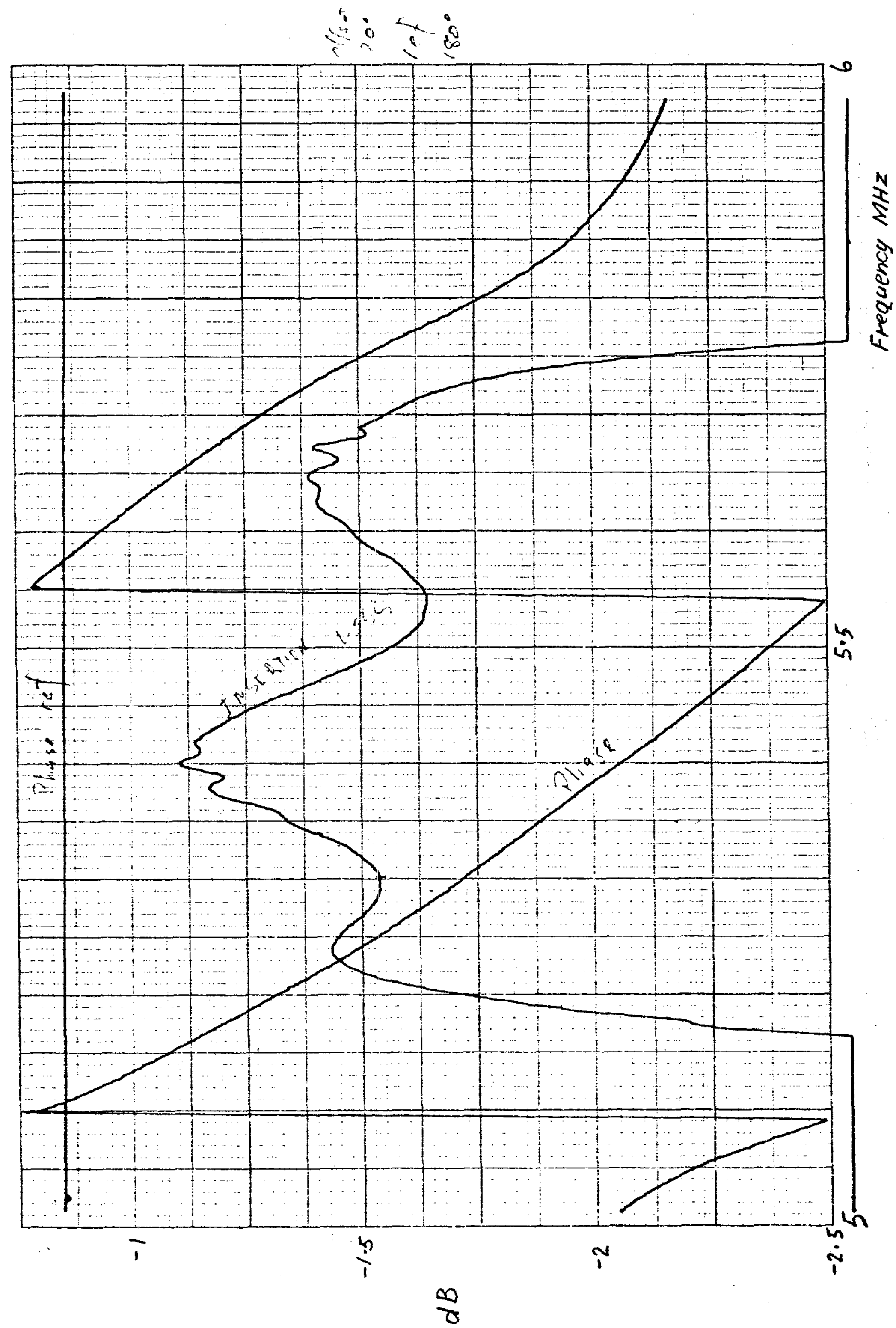


Figure 27. Measured 5.45 MHz band pass filter insertion loss expanded scale and phase about centre frequency (receiver)

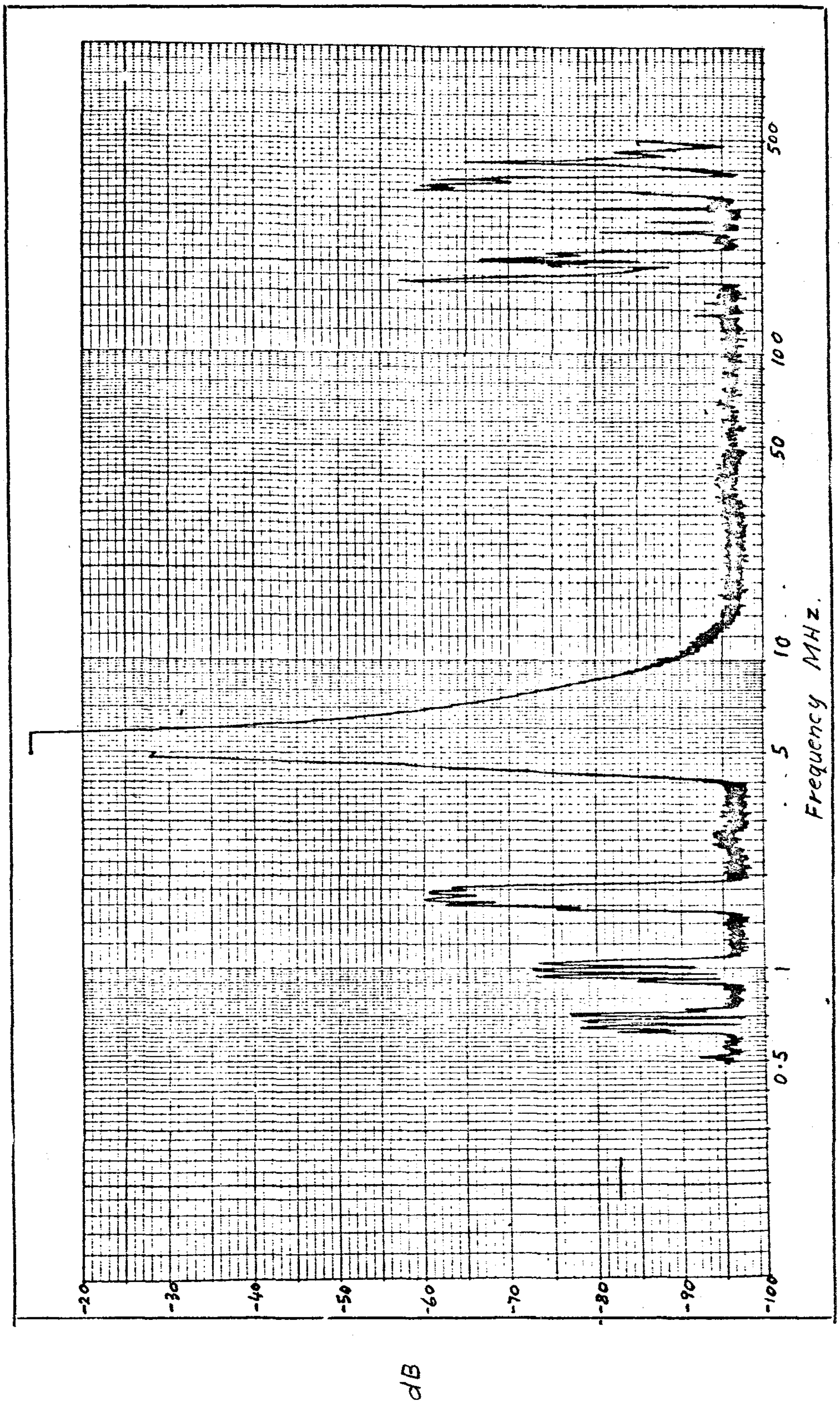
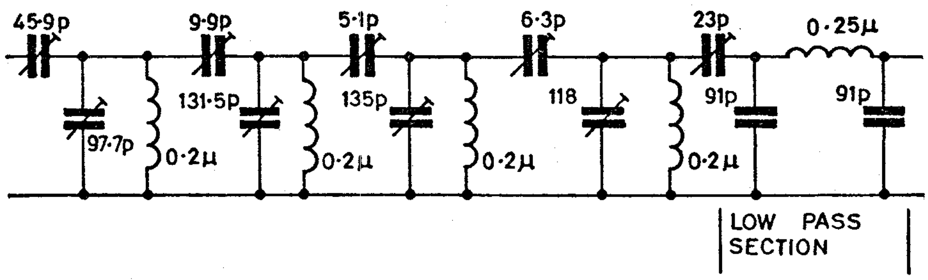


Figure 28. Measured 5.45 MHz band pass filter insertion loss from 0.5 to 500 MHz (receiver signal chain)



FILTER DESIGN DATA: BUTTERWORTH RESPONSE
CENTRE FREQUENCY 29.4 MHz
BANDWIDTH 1.85 MHz
UNLOADED INDUCTOR Q = 200
MATCHED TO 50 Ω AT INPUT AND OUTPUT
LOW PASS SECTION CUT OFF = 50 MHz

ALIGNMENT OF FILTER
FOR METHOD SEE SECTION 9.4 ZVEREV "HANDBOOK OF FILTER SYNTHESIS"

SECTION	WIDTH(MHz)	LOWER FREQ.(MHz)	UPPER FREQ.(MHz)
WORKING FROM INPUT			
BW OF 1ST	3.45472	27.62262	31.07735
BTWN PEAKS 2ND	1.98783	28.35607	30.34391
OUTER PEAKS 3RD	2.23699	28.23149	30.46848
INNER PEAKS 4TH	1.07322	28.81337	29.88660
OUTER PEAKS 4TH	2.33179	28.18410	30.51587
WORKING FROM OUTPUT			
BW OF 1ST	1.09630	28.80184	29.89814
BTWN PEAKS 2ND	1.25892	28.72052	29.97945
OUTER PEAKS 3RD	1.62407	28.53795	30.16202
INNER PEAKS 4TH	1.07322	28.81337	29.88660
OUTER PEAKS 4TH	2.33179	28.18410	30.51587

Figure 29. 29.4 MHz band pass filter

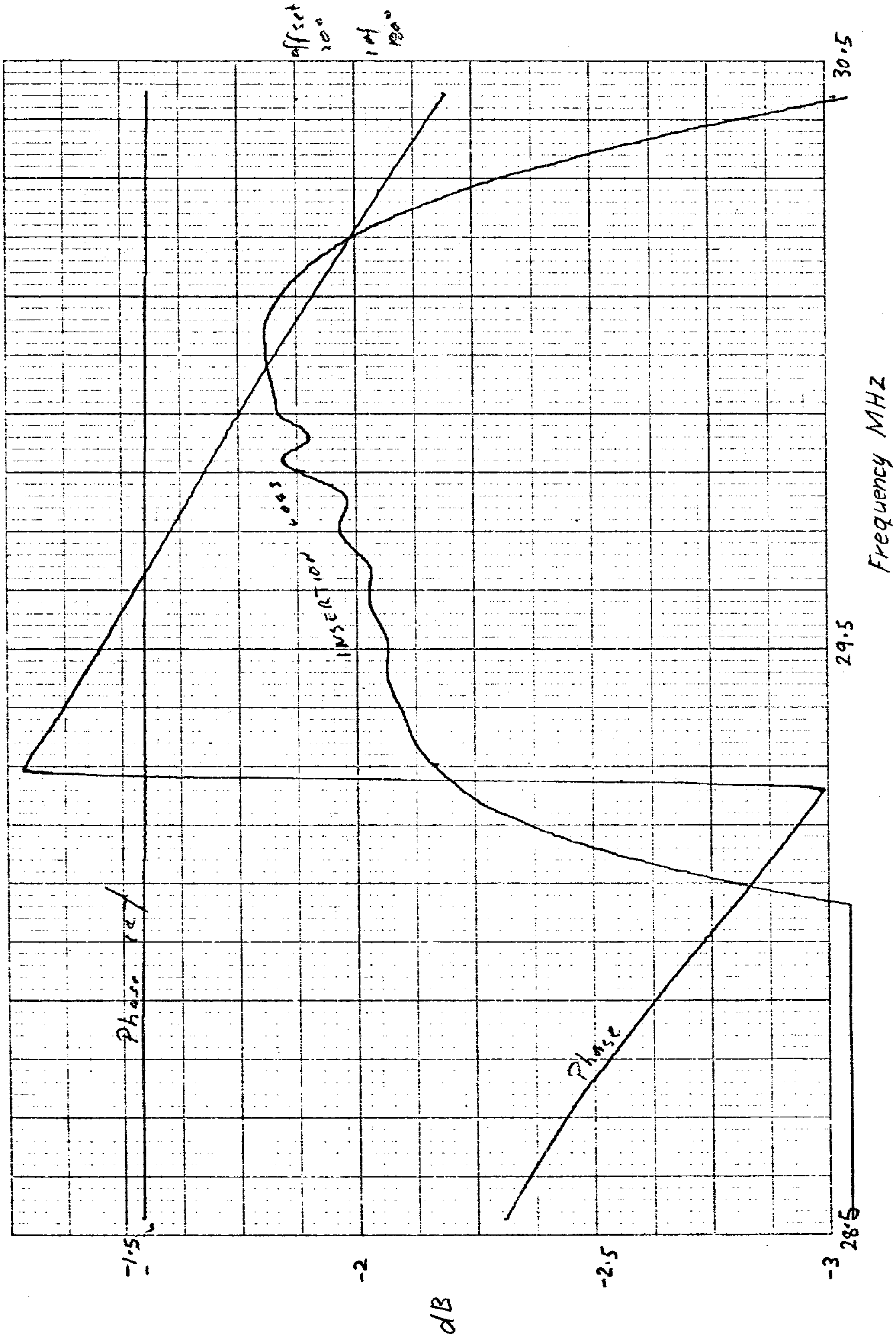


Figure 30. Measured 29.4 MHz band pass filter insertion loss (expanded scale) and phase (receiver signal chain)

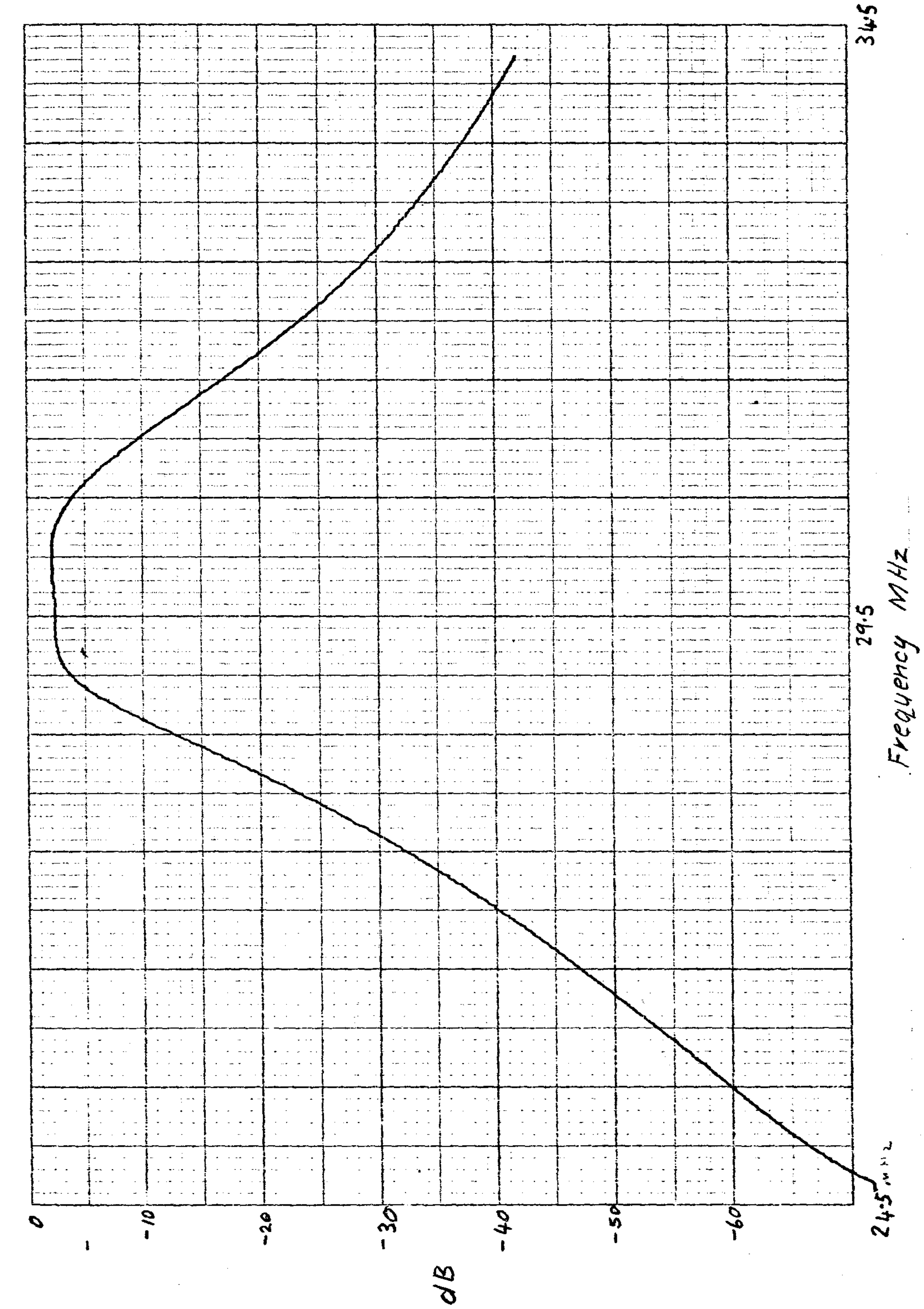


Figure 31. Measured 29.4 MHz band pass filter insertion loss (receiver signal chain)

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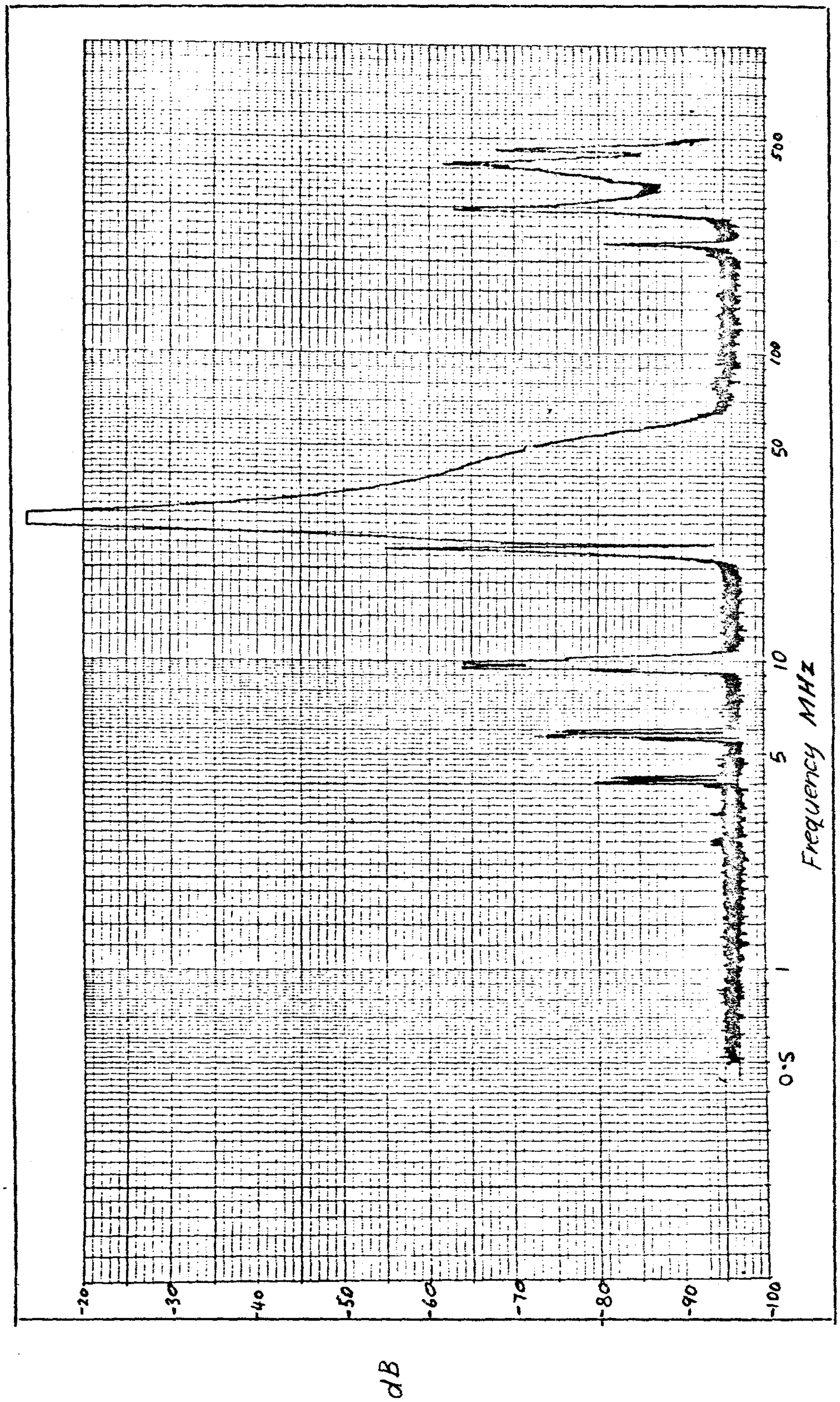
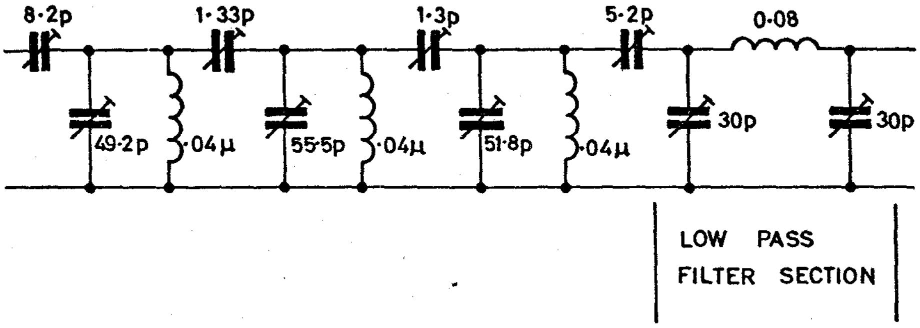


Figure 32. Measured 29.4 MHz band pass filter insertion loss from 0.5 to 500 MHz (receiver signal chain)

UNCLASSIFIED ~~RESTRICTED~~



FILTER DESIGN DATA: BUTTERWORTH RESPONSE
CENTRE FREQUENCY = 104.35 MHz
BANDWIDTH = 3.4 MHz
UNLOADED INDUCTOR Q = 200
MATCHED TO 50 Ω AT INPUT AND OUTPUT
LOW PASS FILTER CUTOFF = 150 MHz

Figure 33. 104.45 MHz band pass filter

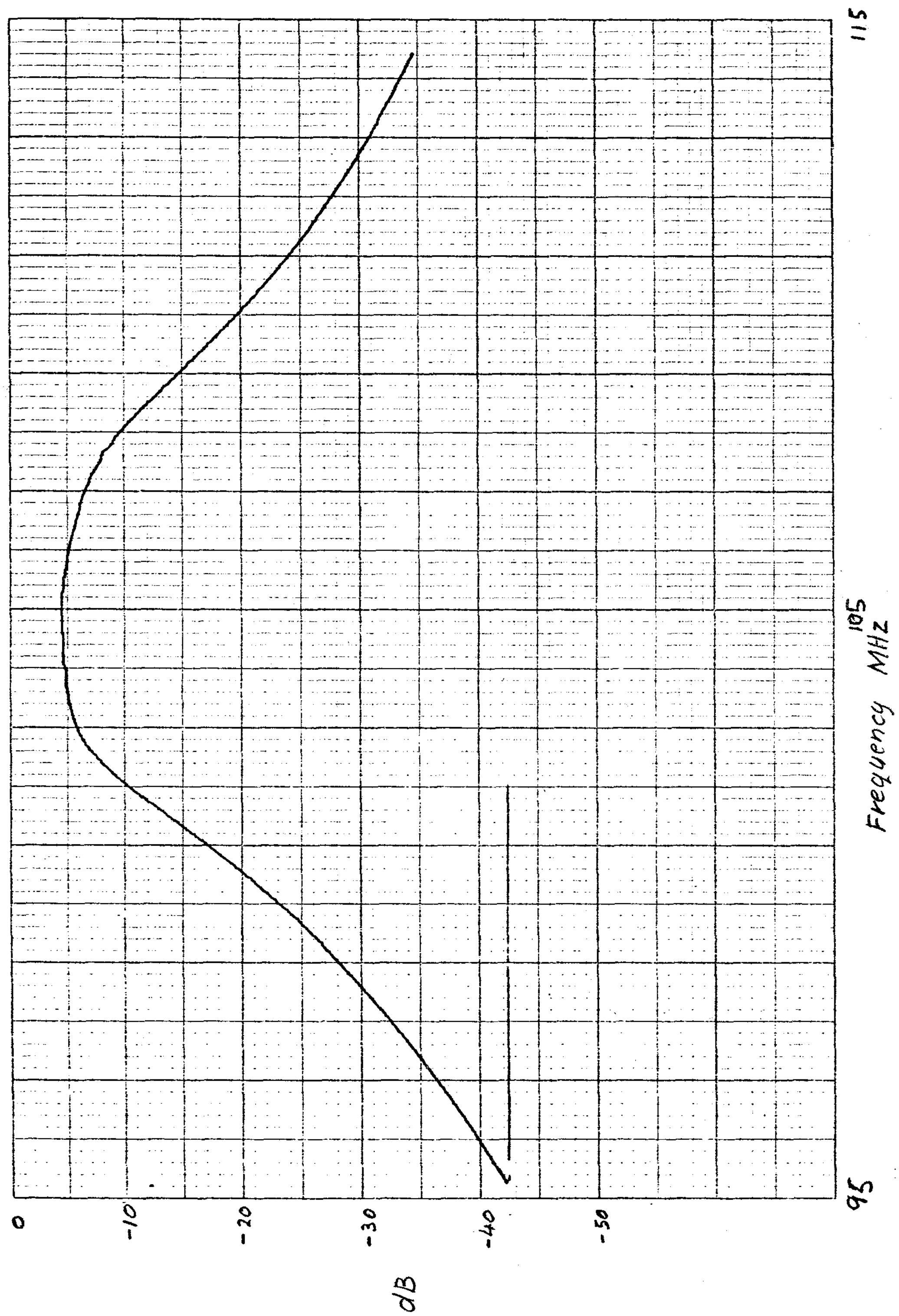


Figure 34. Measured 104.5 MHz band pass filter insertion loss (receiver signal chain)

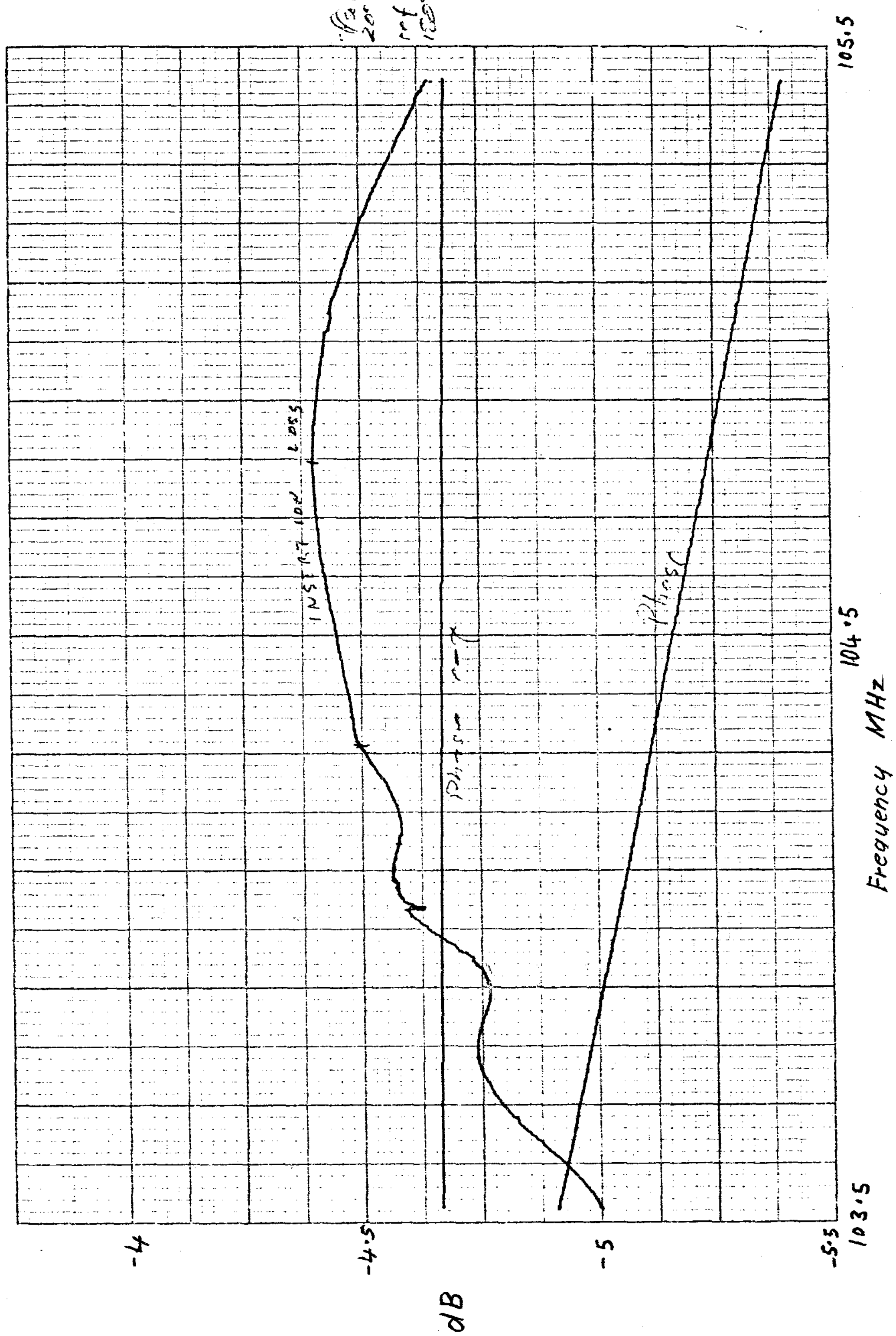


Figure 35. Measured 104 MHz band pass filter insertion loss and phase (expanded scale) (receiver signal chain)

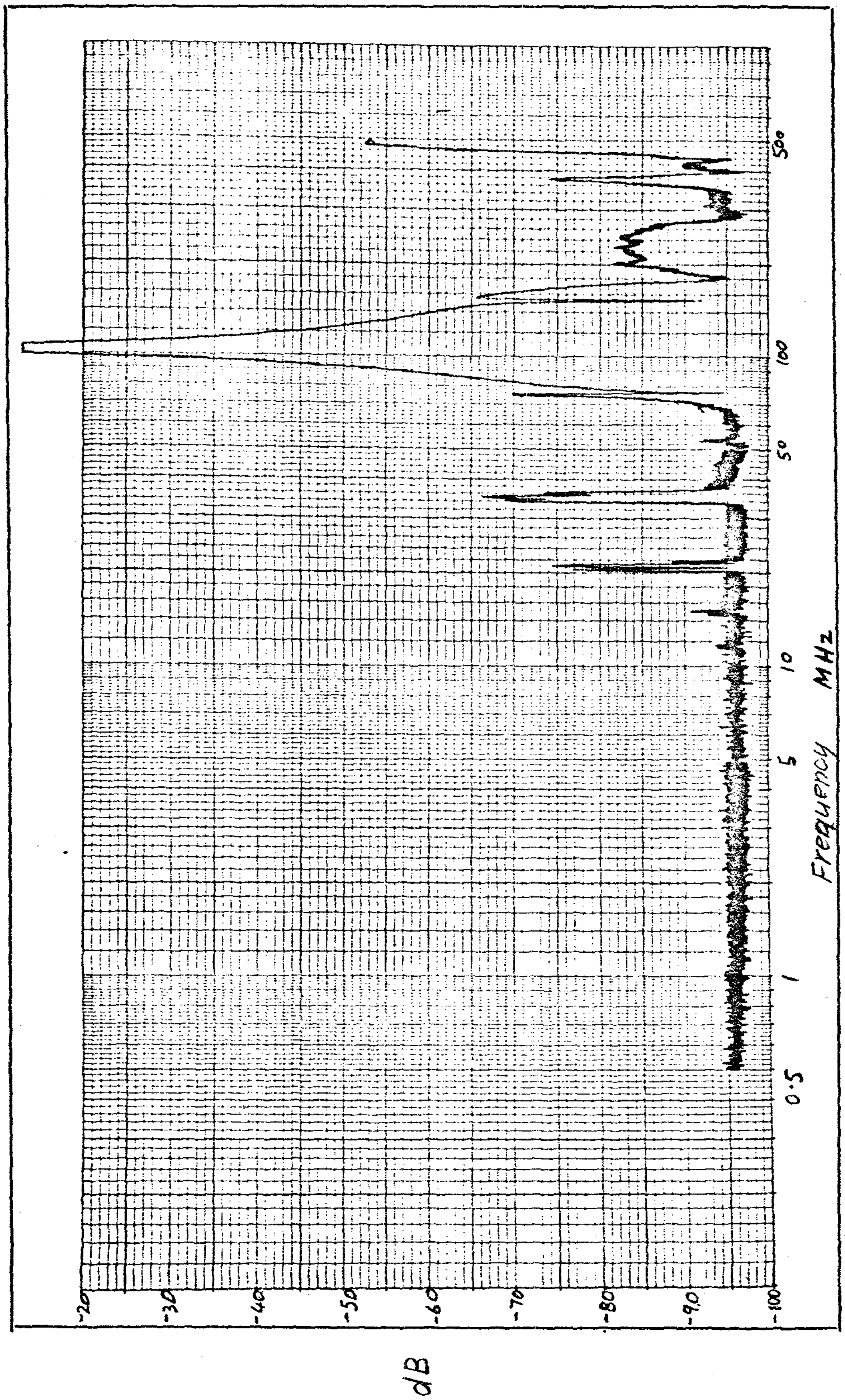
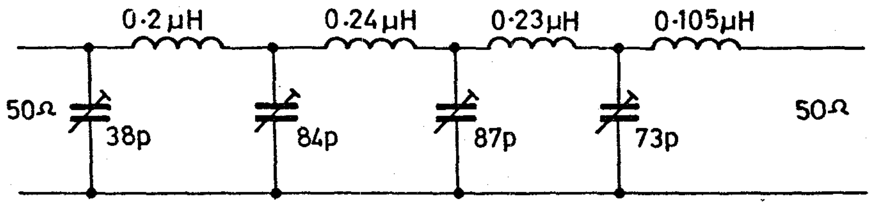


Figure 36. Measured 104 MHz band pass filter insertion loss from 0.5 to 500 MHz (receiver signal chain)



CHEBYSHEV 0·01dB RIPPLE FILTER
CUT OFF FREQUENCY 68·22 MHz

Figure 37. 68 MHz low pass filter at output of receiver chain

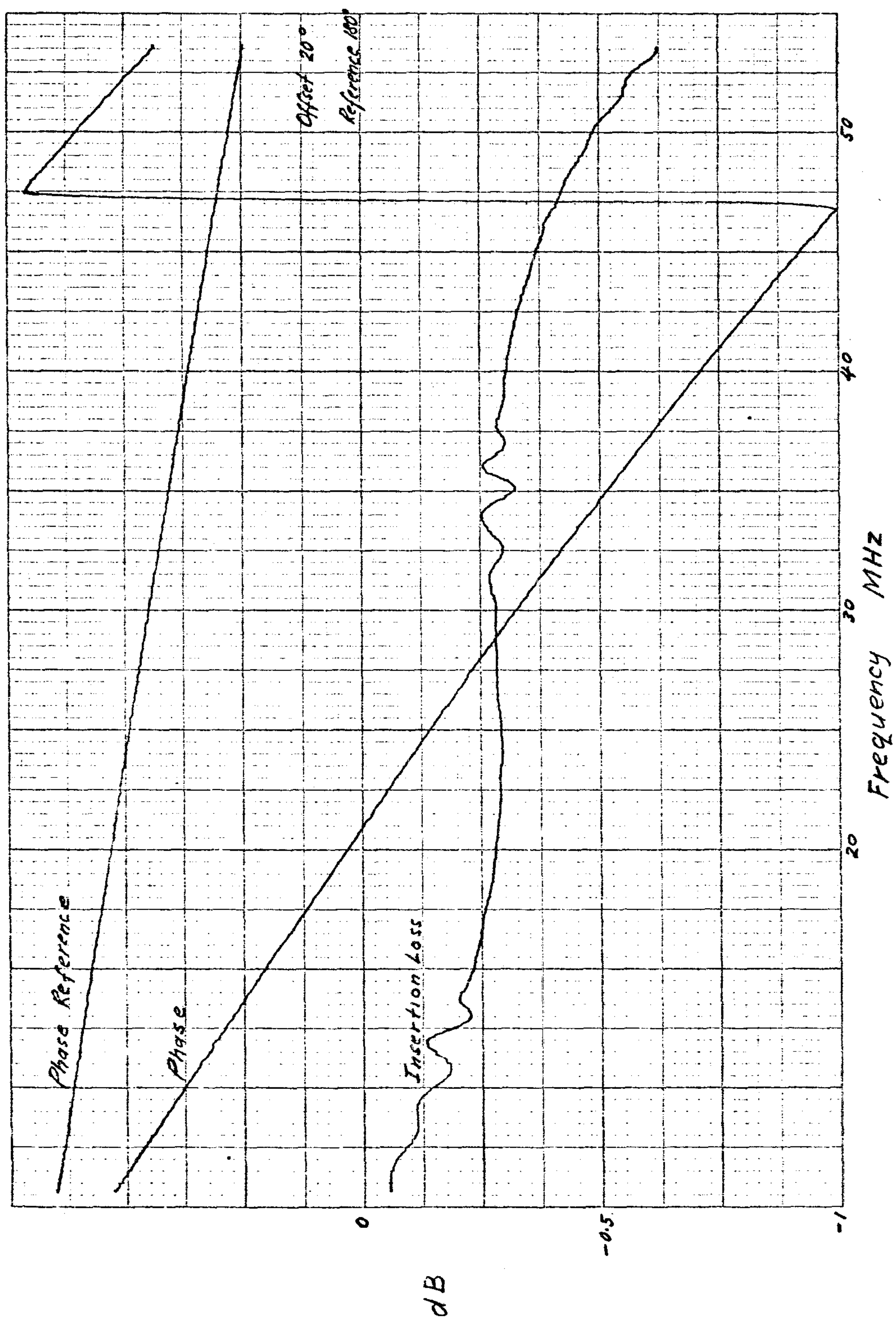


Figure 38. Measured 68 MHz low pass filter insertion loss (expanded scale) and phase about centre frequency (receiver)

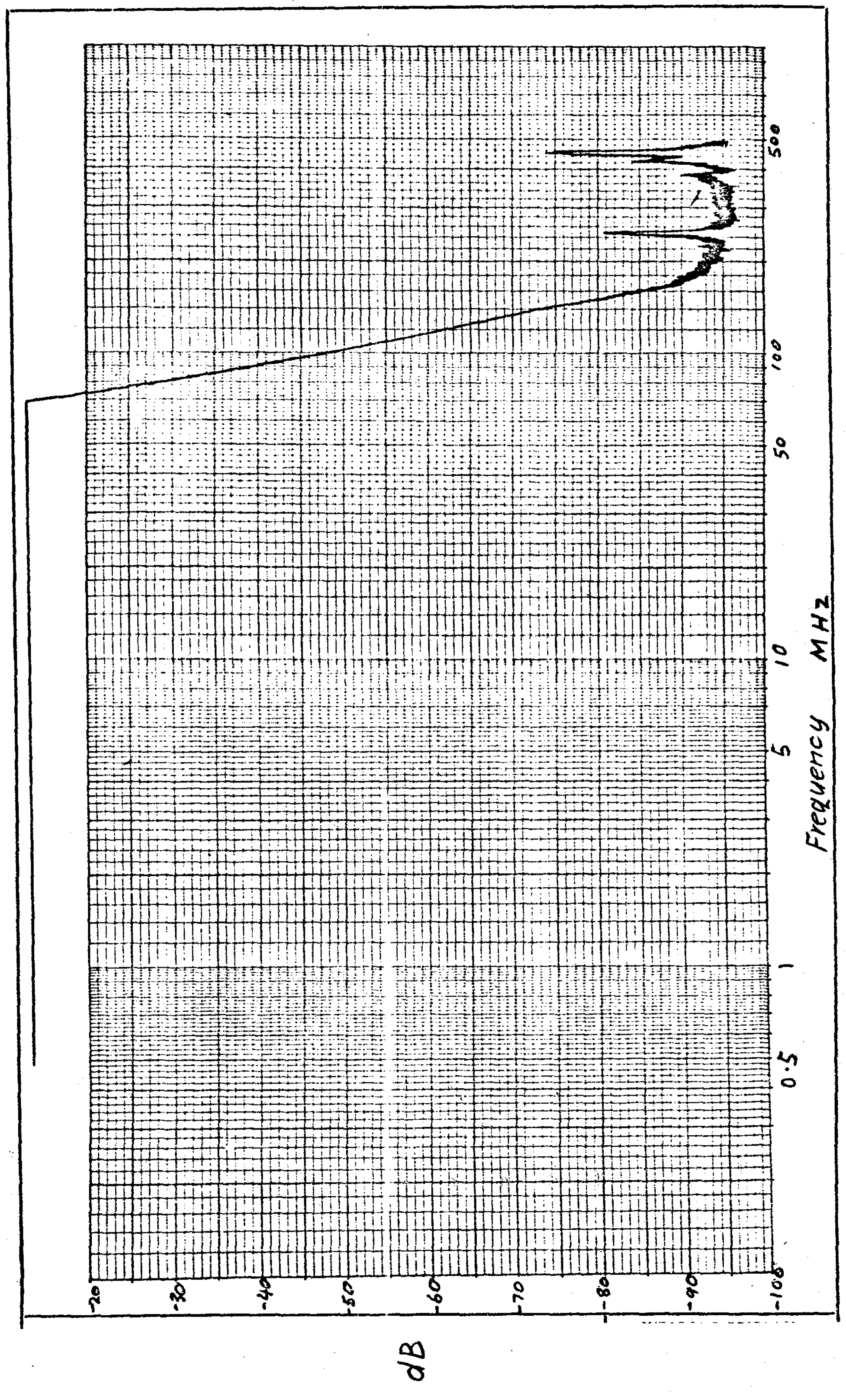
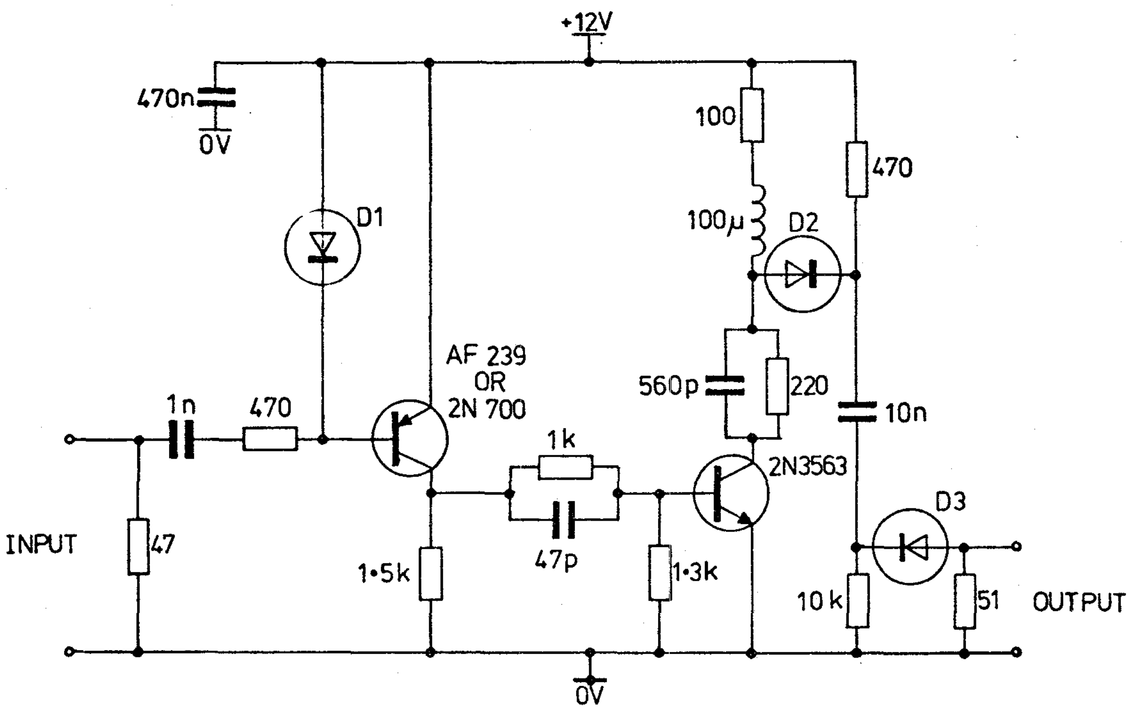


Figure 39. Measured 68 MHz low pass filter insertion loss from 0.5 to 500 MHz (receiver signal chain)



D1 IN3712 - Tunnel Diode (Motorola)
D2 5082 - 0113 Step Recovery Diode (Hewlett Packard)
D3 5082 - 2900 Hot Carrier Diode (Hewlett Packard)
AF239 - WRE Store Number 5961-TN-998-1981

Figure 40. Step recovery diode (low frequency) circuit

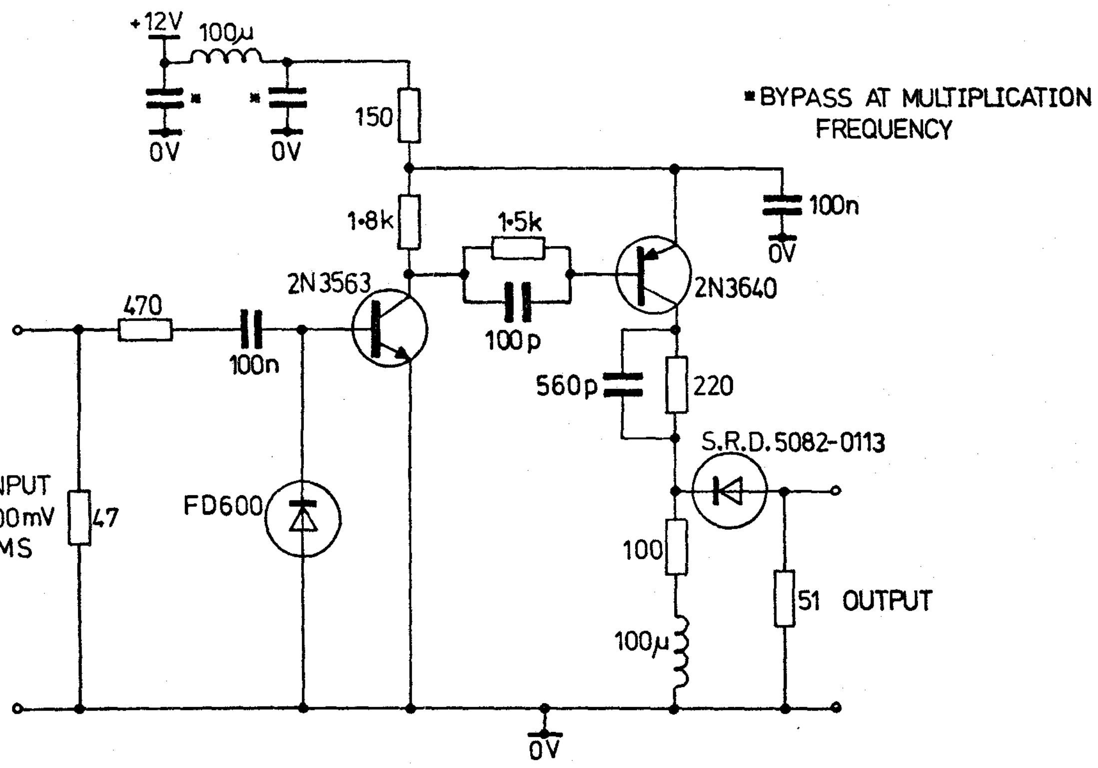


Figure 41. Step recovery diode (high frequency) circuit

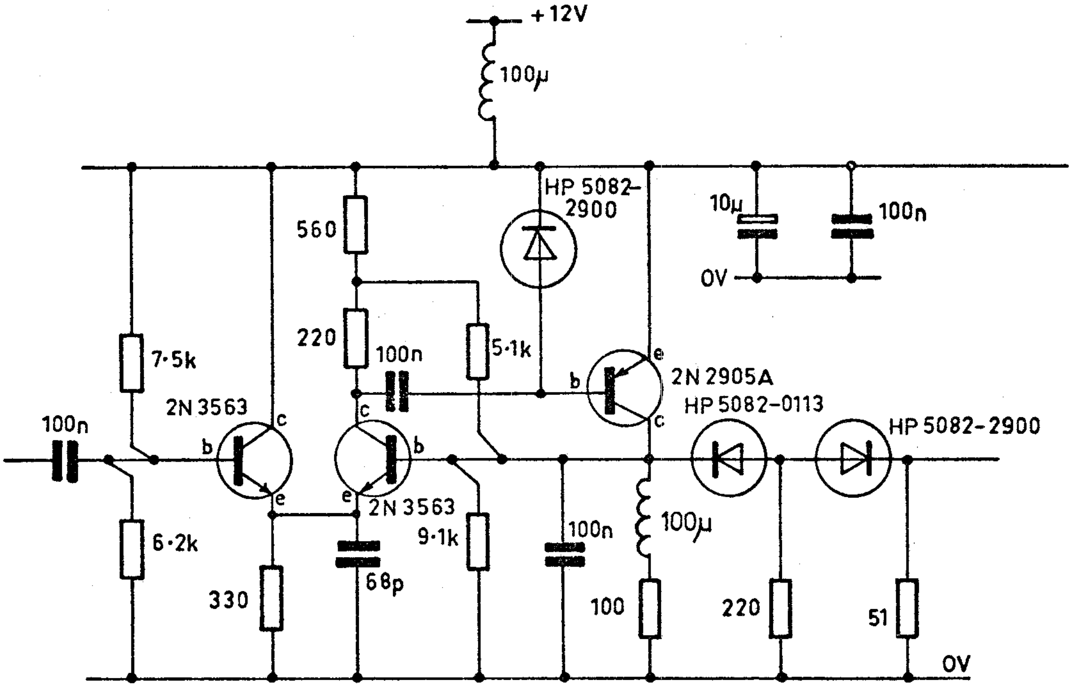
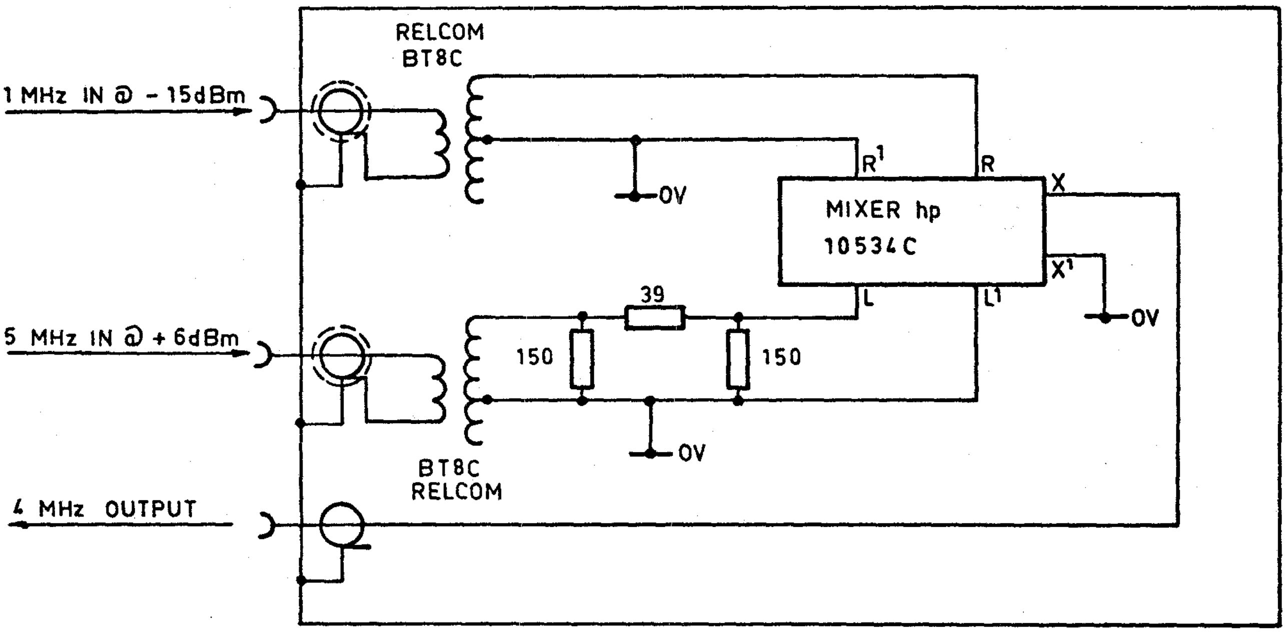
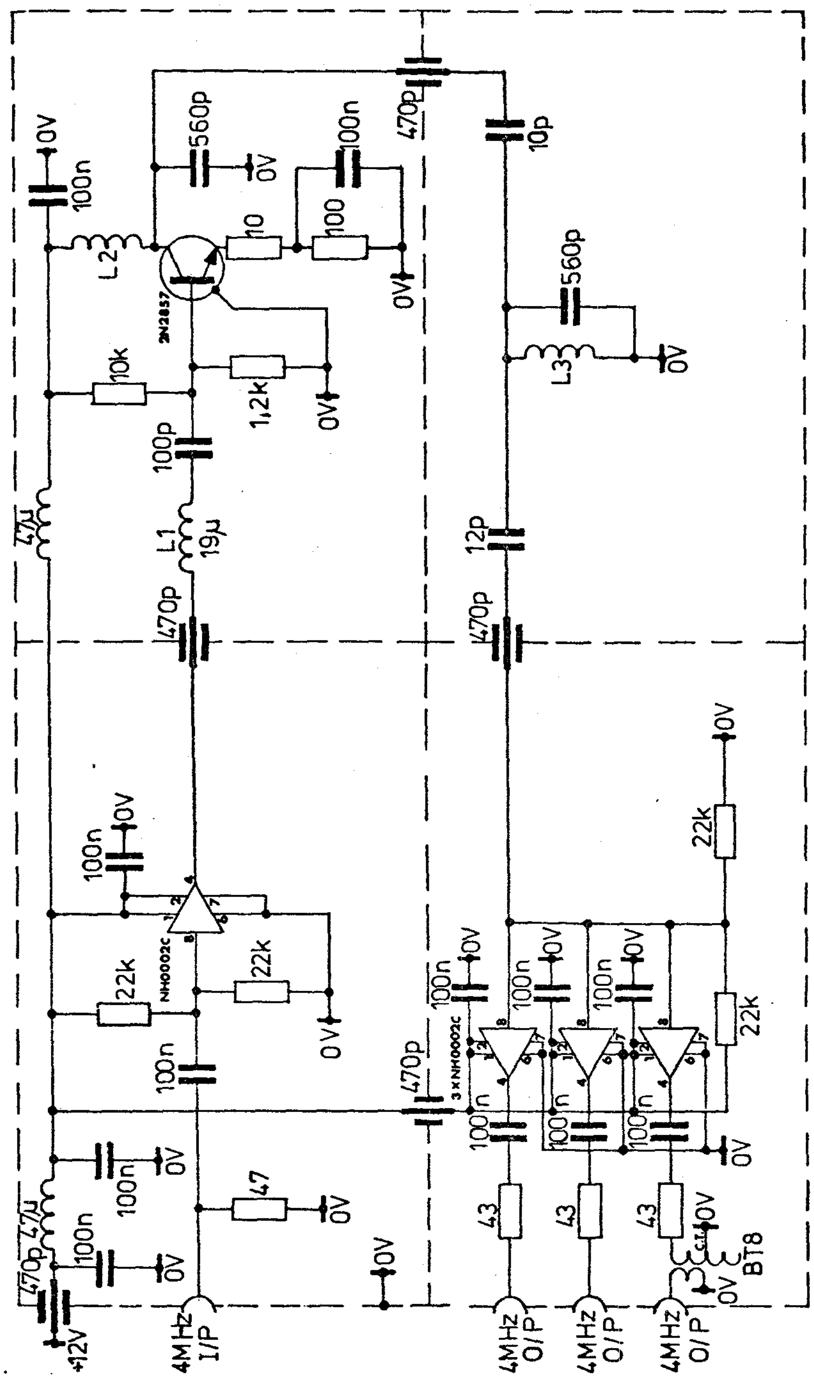


Figure 42. Broad band step recovery diode multiplier circuit



INSULATED BNC CONNECTOR

Figure 43. Transmitter 4 MHz generation



NOTES: L1: 28T 20/44 LIT 2 ON TYPE 'A' NEOSID FORMER WITH TYPE 500 SLUG.
L2,3: 16T 20/44 LIT 2 ON TYPE 'A' NEOSID FORMER WITH TYPE 500 SLUG.

Figure 44. 4 MHz transmitter amplifier with multiple outputs

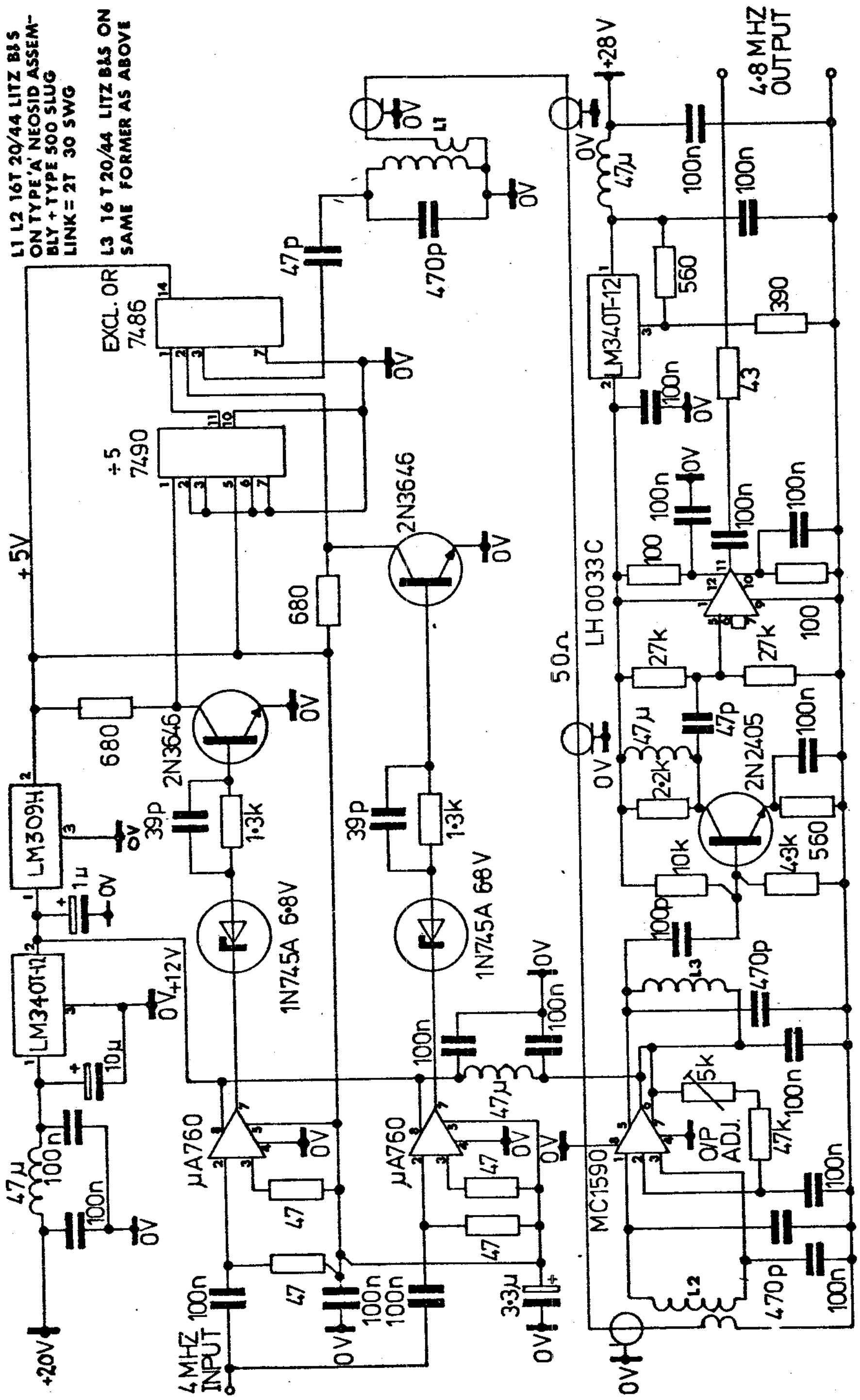


Figure 45. Circuit for generating 4.8 MHz local oscillator (transmitter local oscillator chain)

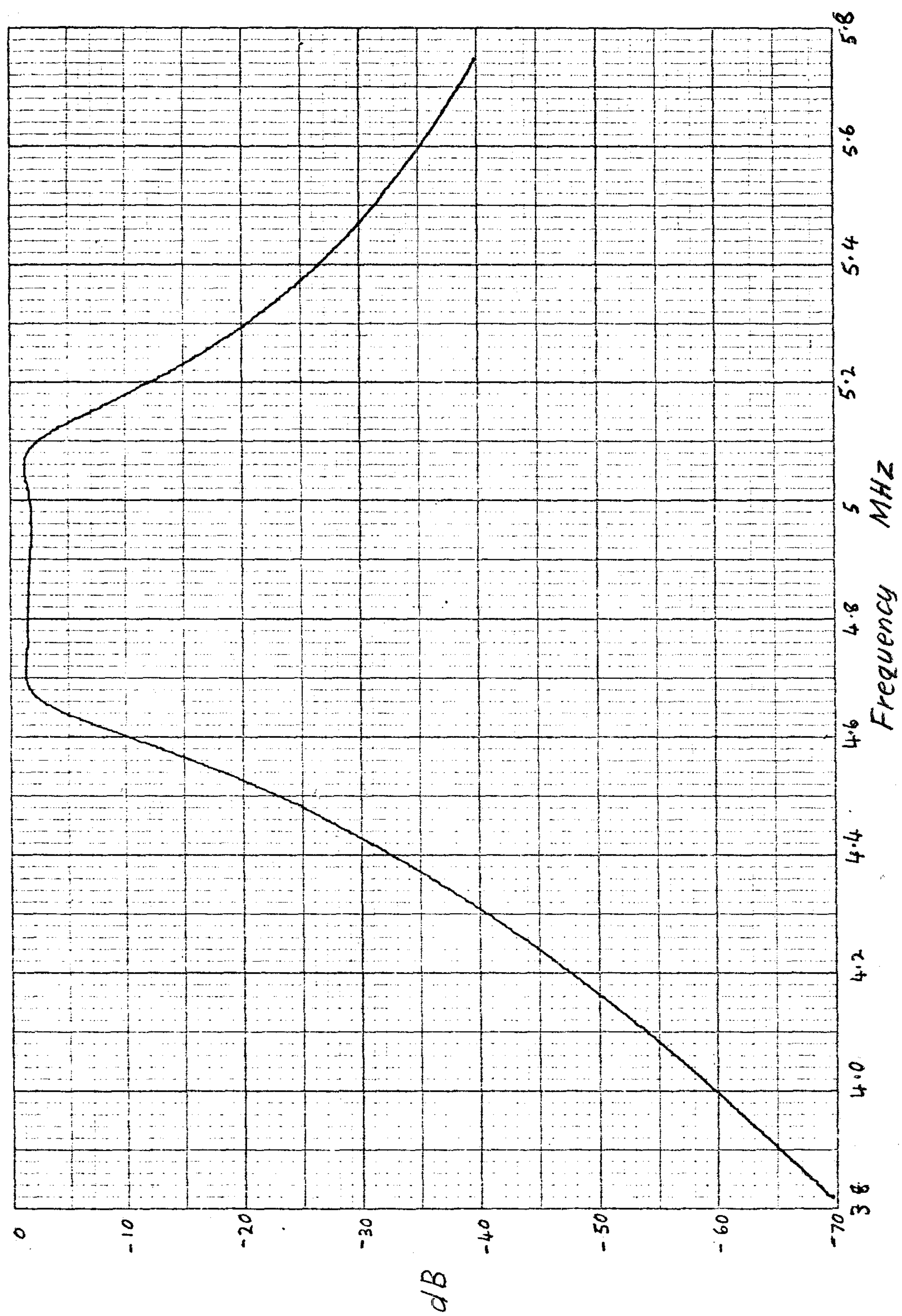


Figure 46. Measured 4.8 MHz band pass filter insertion loss (transmitter local oscillator chain)

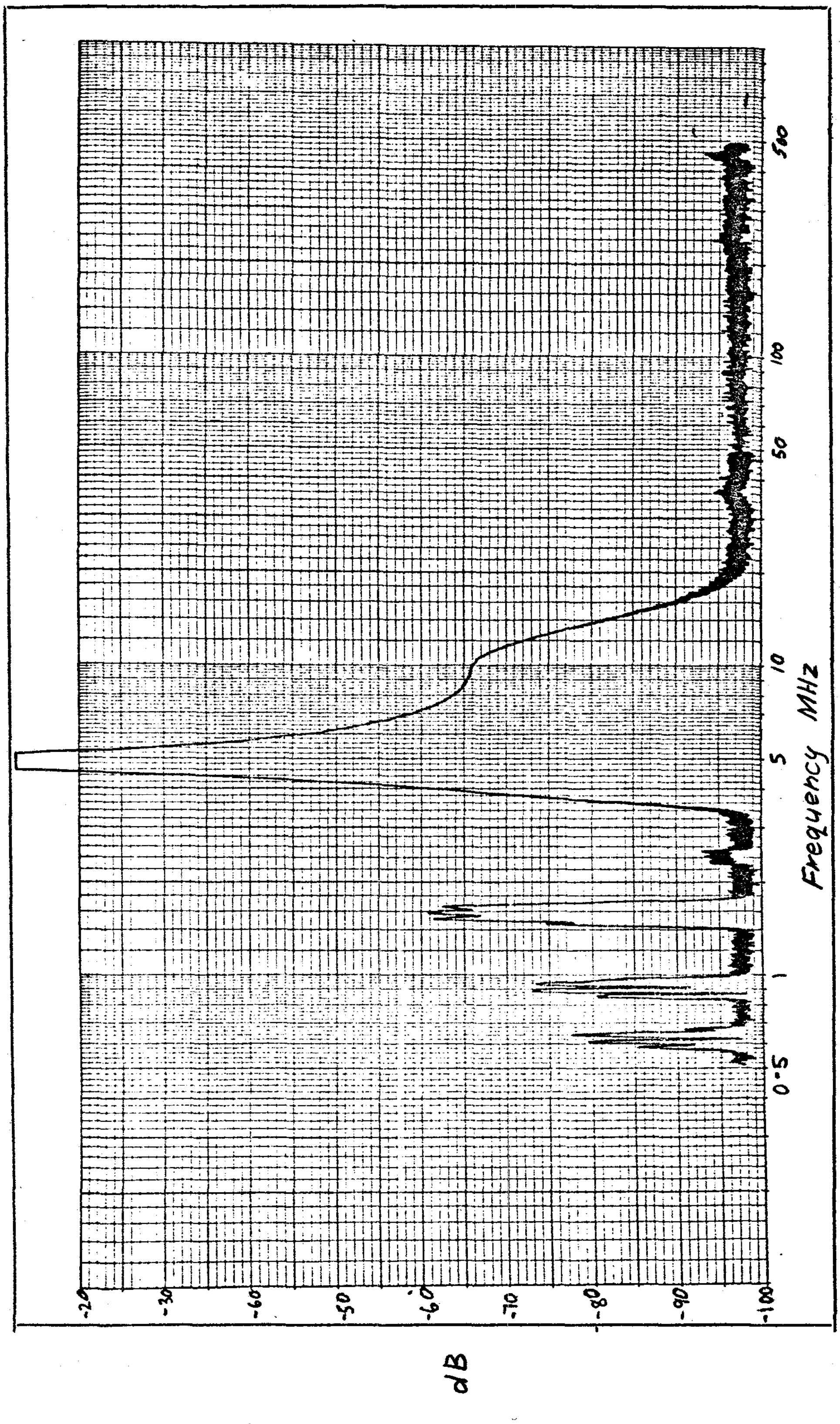


Figure 47. Measured 4.8 MHz band pass filter insertion loss from 0.5 to 500 MHz (transmitter local oscillator chain)

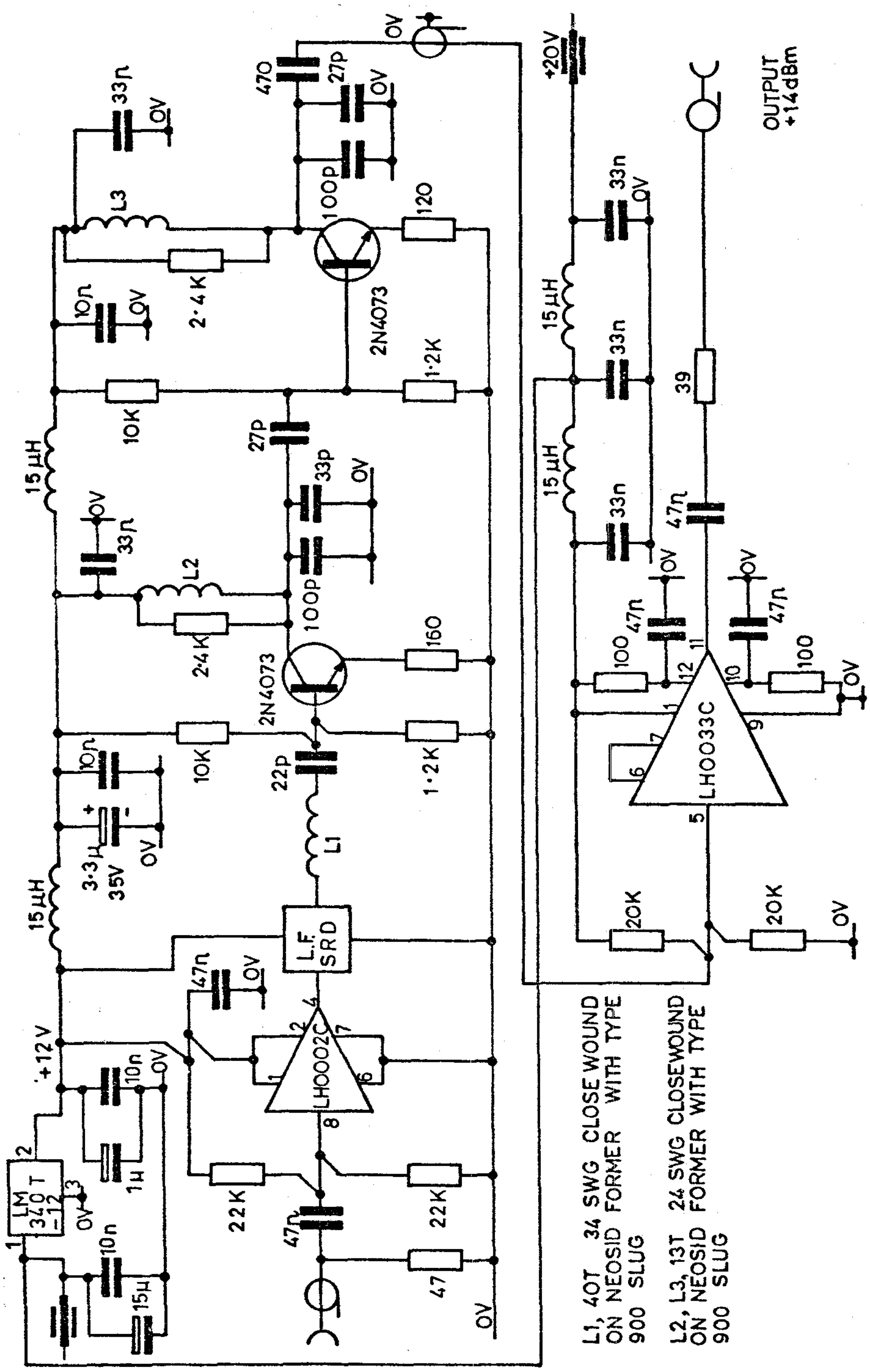
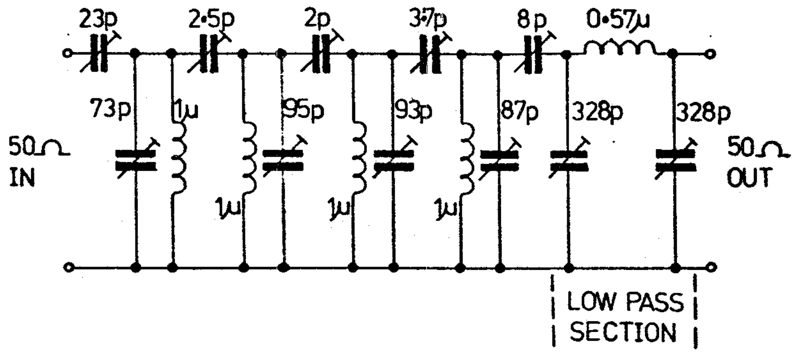


Figure 48. 16 MHz amplifier



NOTES:

1. INDUCTORS: 1 μH 9 TURNS 14 GAUGE 30 MM LONG, 22 MM DIA. AIR WOUND
0.56 μH 8 TURNS 16 GAUGE 21 MM LONG, 15 MM DIA. AIR WOUND

2. FILTER DESIGN DATA: CHEBYSHEV 0.5 dB RIPPLE
CENTRE FREQUENCY = 16 MHz
BANDWIDTH = 0.75 MHz
UNLOADED INDUCTOR Q = 190
LOW PASS FILTER CUT OFF = 18 MHz

ALIGNMENT OF FILTER
FOR METHOD SEE SECTION 9.4 ZVEREV "HANDBOOK OF FILTER SYNTHESIS"

SECTION	WIDTH (MHz)	LOWER FREQ. (MHz)	UPPER FREQ. (MHz)
WORKING FROM INPUT			
BW OF 1ST	0.51685	15.74158	16.25842
BTWN PEAKS 2ND	0.40852	15.79574	16.20425
OUTER PEAKS 3RD	0.51596	15.74202	16.25797
INNER PEAKS 4TH	0.34291	15.82855	16.17145
OUTER PEAKS 4TH	0.70927	15.64536	16.35463
WORKING FROM OUTPUT			
BW OF 1ST	0.13628	15.93186	16.06813
BTWN PEAKS 2ND	0.59535	15.70233	16.29767
OUTER PEAKS 3RD	0.67362	15.66319	16.33681
INNER PEAKS 4TH	0.34291	15.82855	16.17145
OUTER PEAKS 4TH	0.70927	15.64536	16.35463

Figure 49. 16 MHz band pass filter

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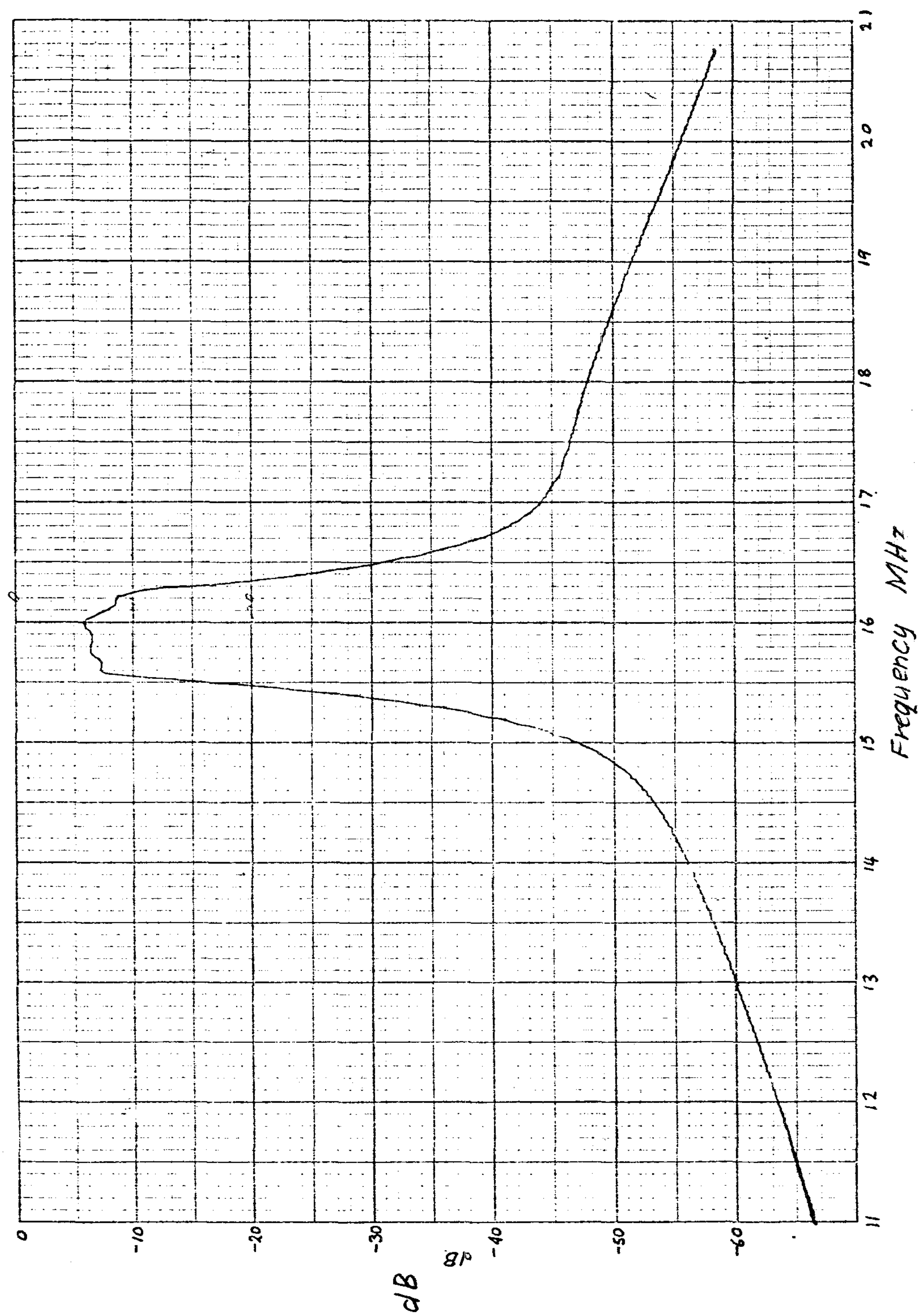

Figure 50. Measured 16 MHz band pass filter insertion loss (transmitter local oscillator chain)

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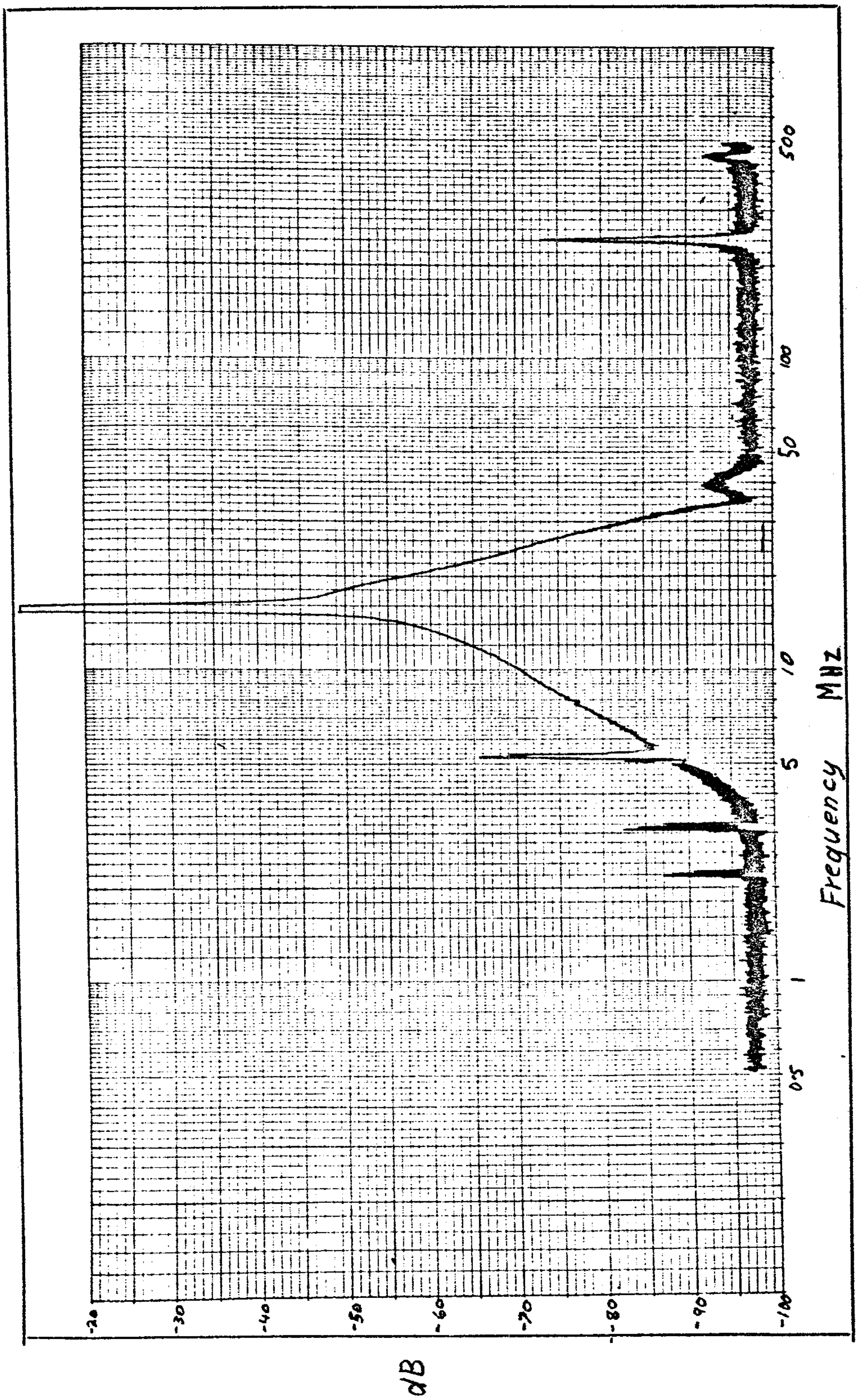
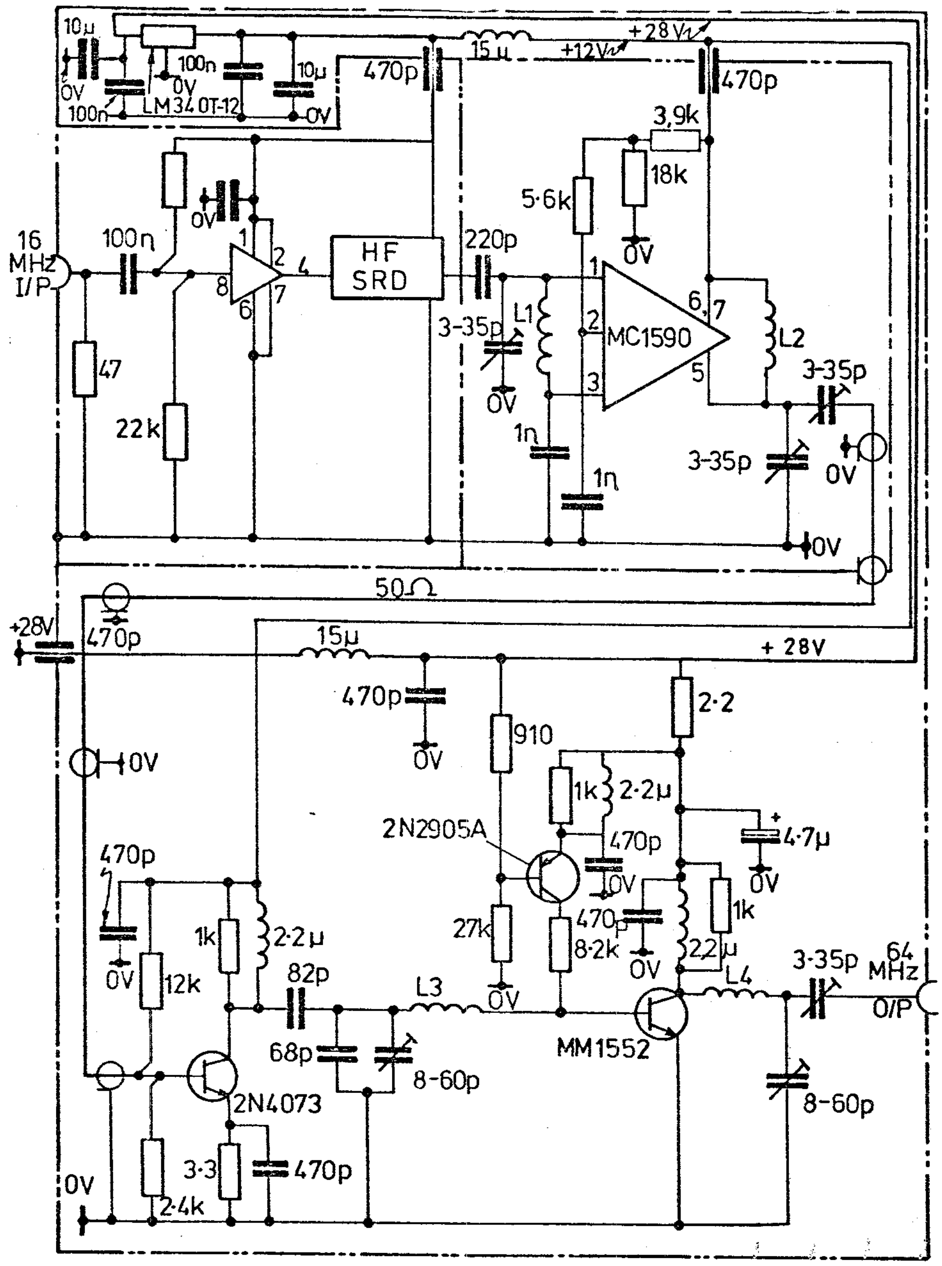
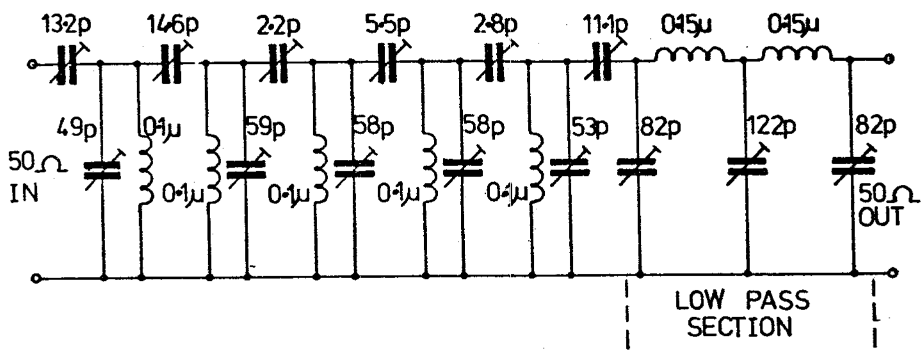


Figure 51. Measured 16 MHz band pass filter insertion loss from 0.5 to 500 MHz (transmitter local oscillator chain)



NOTE: L1 = 7T 18 SWG 7·937 DIA DOUBLE SPACED 12·700 LONG
L2 = 6T 18 SWG 11·112 DIA DOUBLE SPACED 12·700 LONG
L3 = 3T 16 SWG 6·35 DIA 6·35 LONG
L4 = 7T 16 SWG 19·05 DIA 19·05 LONG

Figure 52. 64 MHz amplifier (transmitter local oscillator chain)



NOTES:

1. INDUCTORS: 0.1 µH 2.75 TURNS 16 GAUGE GOLD PLATED COPPER WIRE 11 MM DIA. 8 MM LONG
   0.15 µH 5 TURNS 18 GAUGE COPPER WIRE ON NEOSID POLY-FORMER WITH F29 SLUG

2. FILTER DESIGN DATA: CHEBYSHEV 0.5 dB RIPPLE
   CENTRE FREQUENCY = 62 MHz
   BANDWIDTH = 6.25 MHz
   UNLOADED INDUCTOR Q = 150

ALIGNMENT OF FILTER DATA
FOR METHOD SEE SECTION 9.4 ZVEREV "HANDBOOK OF FILTER SYNTHESIS"

SECTION	WIDTH(MHz)	LOWER FREQ.(MHz)	UPPER FREQ.(MHz)
WORKING FROM INPUT			
BW OF 1ST	3.38789	60.30605	63.69394
BTWN PEAKS 2ND	4.33160	59.83420	64.16579
OUTER PEAKS 3RD	4.79559	59.60220	64.39778
INNER PEAKS 4TH	3.74737	60.12631	63.87367
OUTER PEAKS 4TH	5.96636	59.01682	64.98317
WORKING FROM OUTPUT			
BW OF 1ST	2.57018	60.71490	63.28508
BTWN PEAKS 2ND	2.59350	60.70325	63.29674
OUTER PEAKS 3RD	5.77658	59.11171	64.88828
INNER PEAKS 4TH	0.87944	61.56027	62.43971
OUTER PEAKS 4TH	6.06880	58.96559	65.03439

TRIMMERS JFD MC603Y, MC601Y, PADDED WITH NPO PHILIPS METAL PLATE WHERE NECESSARY.

Figure 53. Band pass filter at output of 64 MHz local oscillator chain

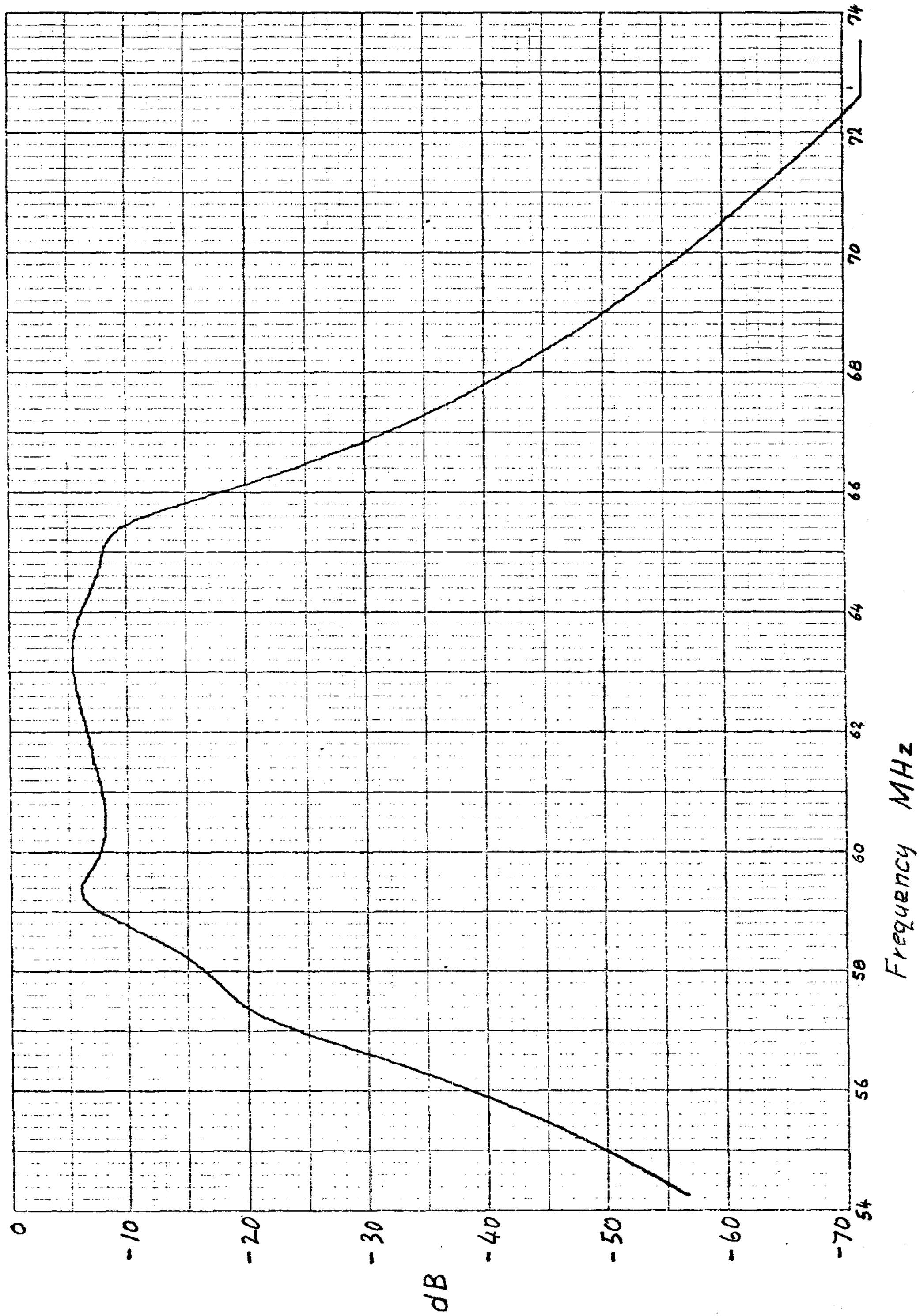


Figure 54. Measured 64 MHz band pass filter insertion loss (transmitter local oscillator chain)

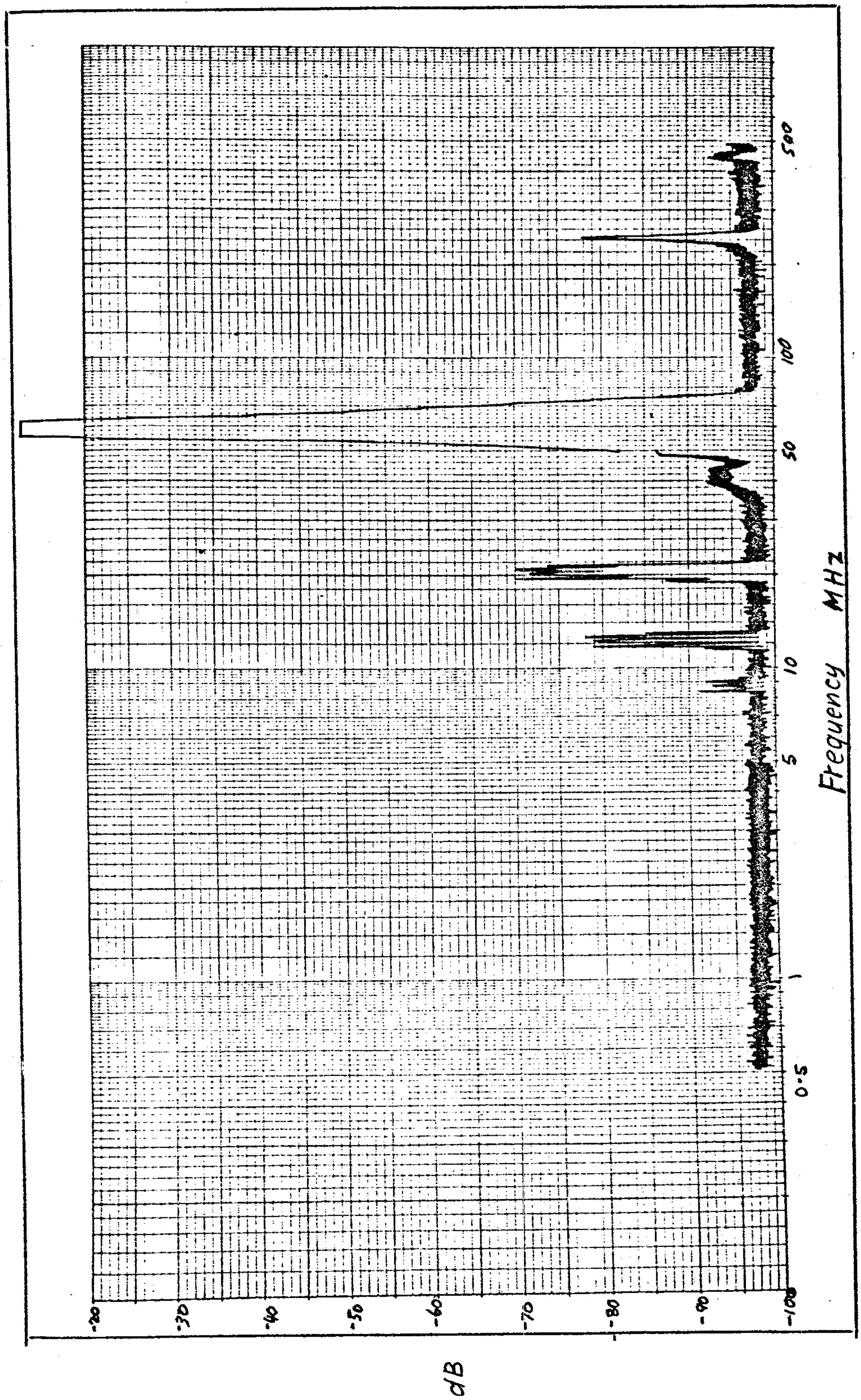
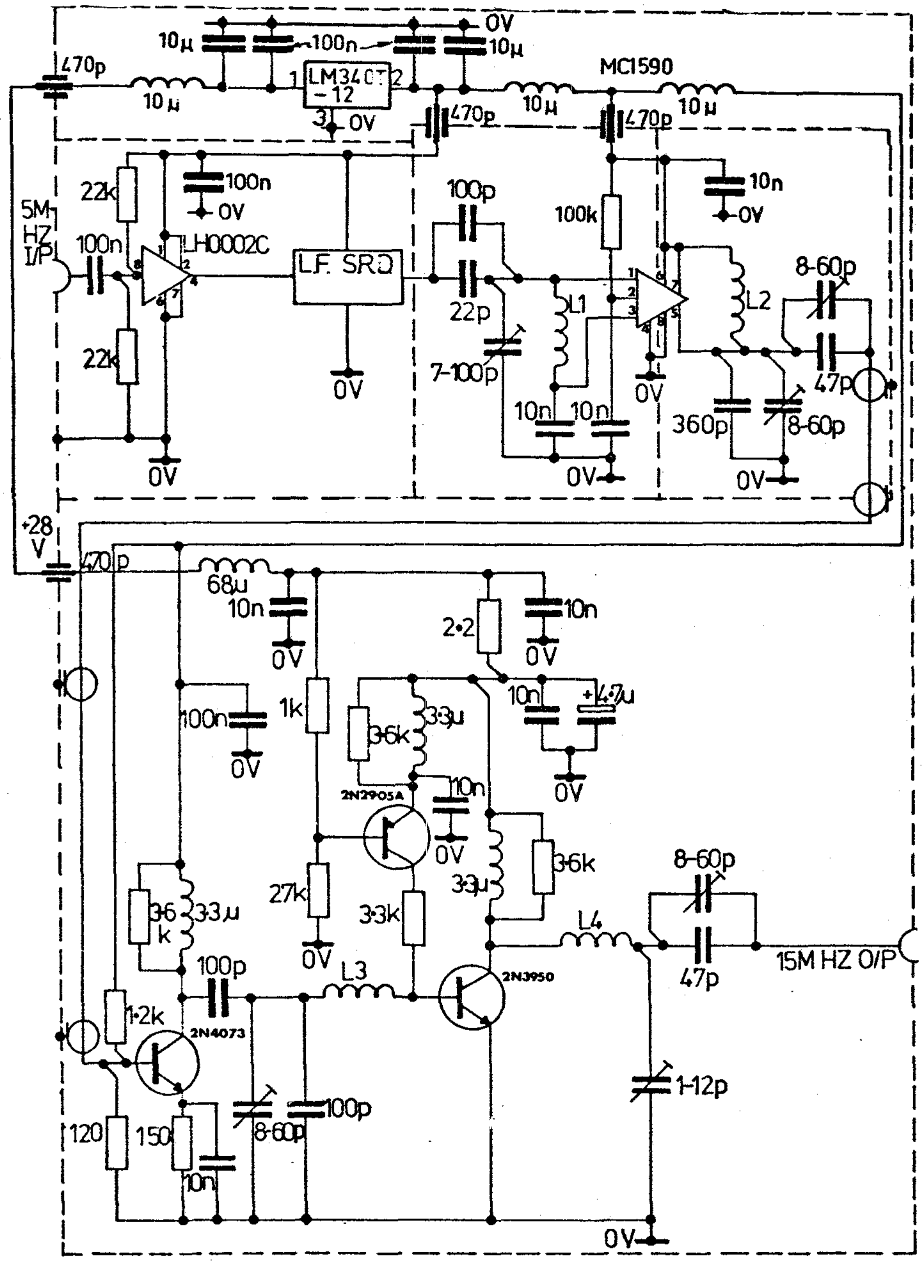


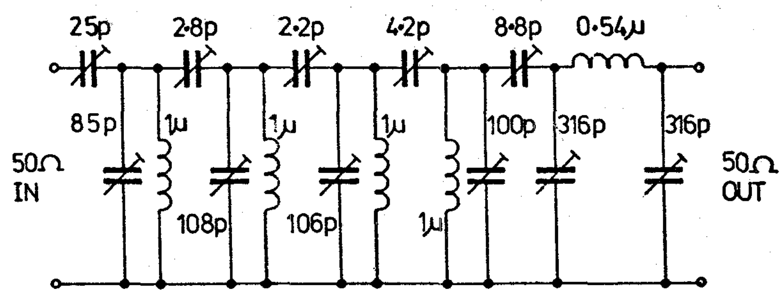
Figure 55. Measured 64 MHz band pass filter insertion loss from 0.5 to 500 MHz (transmitter local oscillator chain)



NOTES:

L1 13T 24 SWG TCW ON NEOSID FORMER WITH 900 SLUG
L2 7T 20 SWG TCW ON FORMER 9MM DIA. DOUBLE SPACED ≃ 10 MM LONG
L3 15T 24 SWG TCW ON NEOSID FORMER WITH 900 SLUG
L4 5T 19 SWG TCW ON FERRITE RING CORE (4327 R/1/F25/FC)

Figure 56. 15 MHz amplifier for transmitter local oscillator chain



FILTER DESIGN DATA: CHEBYSHEV 0.5 dB RIPPLE
CENTRE FREQUENCY = 15 MHz
BANDWIDTH = 0.7 MHz
UNLOADED COIL Q = 190
LOW PASS CUT OFF FREQUENCY = 18.8 MHz

ALIGNMENT OF FILTER
FOR METHOD SEE SECTION 9.4 ZVEREV "HANDBOOK OF FILTER SYNTHESIS"

SECTION	WIDTH (MHz)	LOWER FREQ. (MHz)	UPPER FREQ. (MHz)
WORKING FROM INPUT			
BW OF 1ST	0.48239	14.75880	15.24120
BTWN PEAKS 2ND	0.38129	14.80935	15.19064
OUTER PEAKS 3RD	0.48156	14.75922	15.24078
INNER PEAKS 4TH	0.32005	14.83998	15.16002
OUTER PEAKS 4TH	0.66199	14.66901	15.33099
WORKING FROM OUTPUT			
BW OF 1ST	0.12719	14.93640	15.06360
BTWN PEAKS 2ND	0.55566	14.72217	15.27783
OUTER PEAKS 3RD	0.62871	14.68564	15.31435
INNER PEAKS 4TH	0.32005	14.83998	15.16002
OUTER PEAKS 4TH	0.66199	14.66901	15.33099

Figure 57. 15 MHz band pass filter

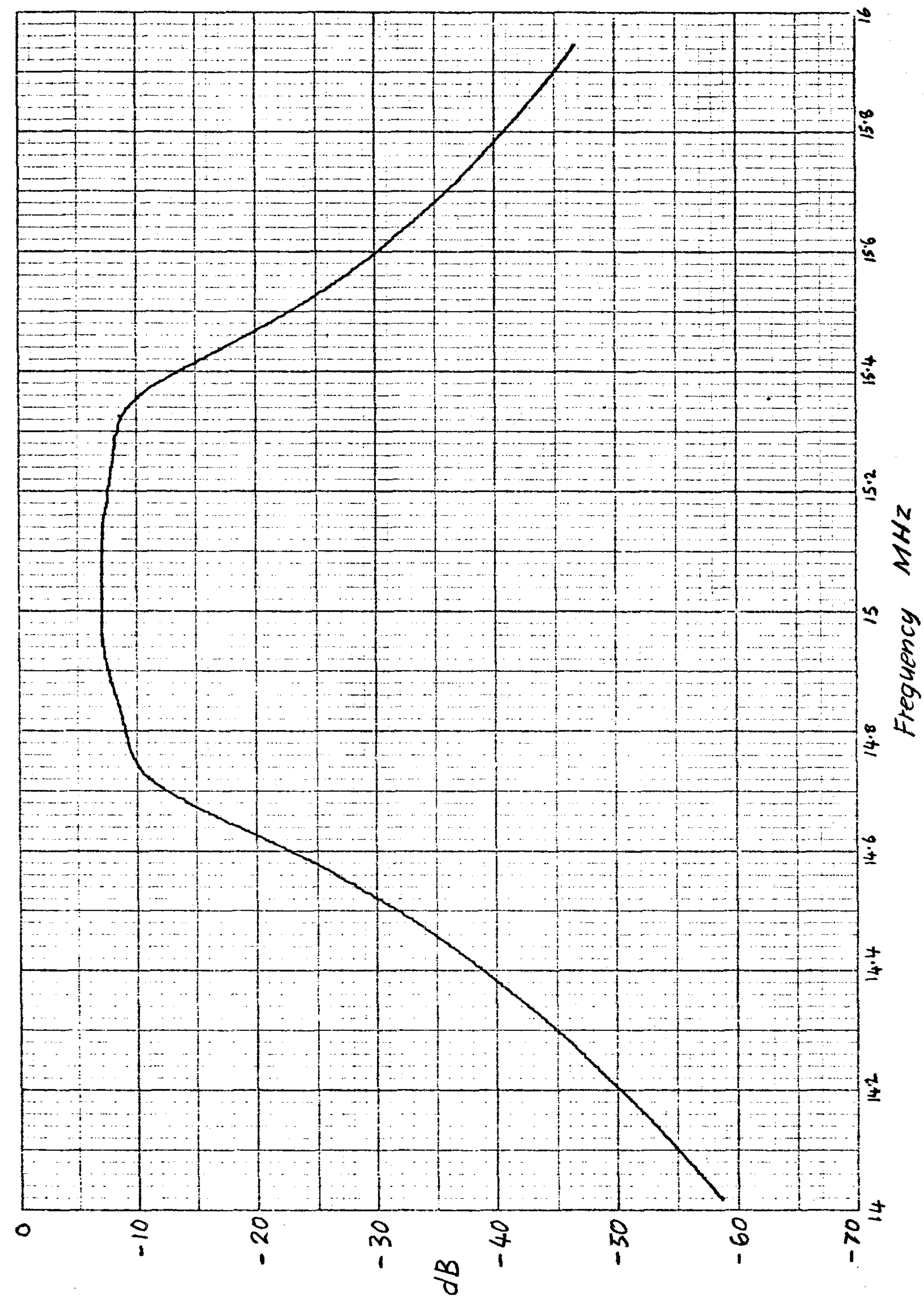


Figure 58. Measured 15 MHz band pass filter insertion loss (transmitter local oscillator chain)

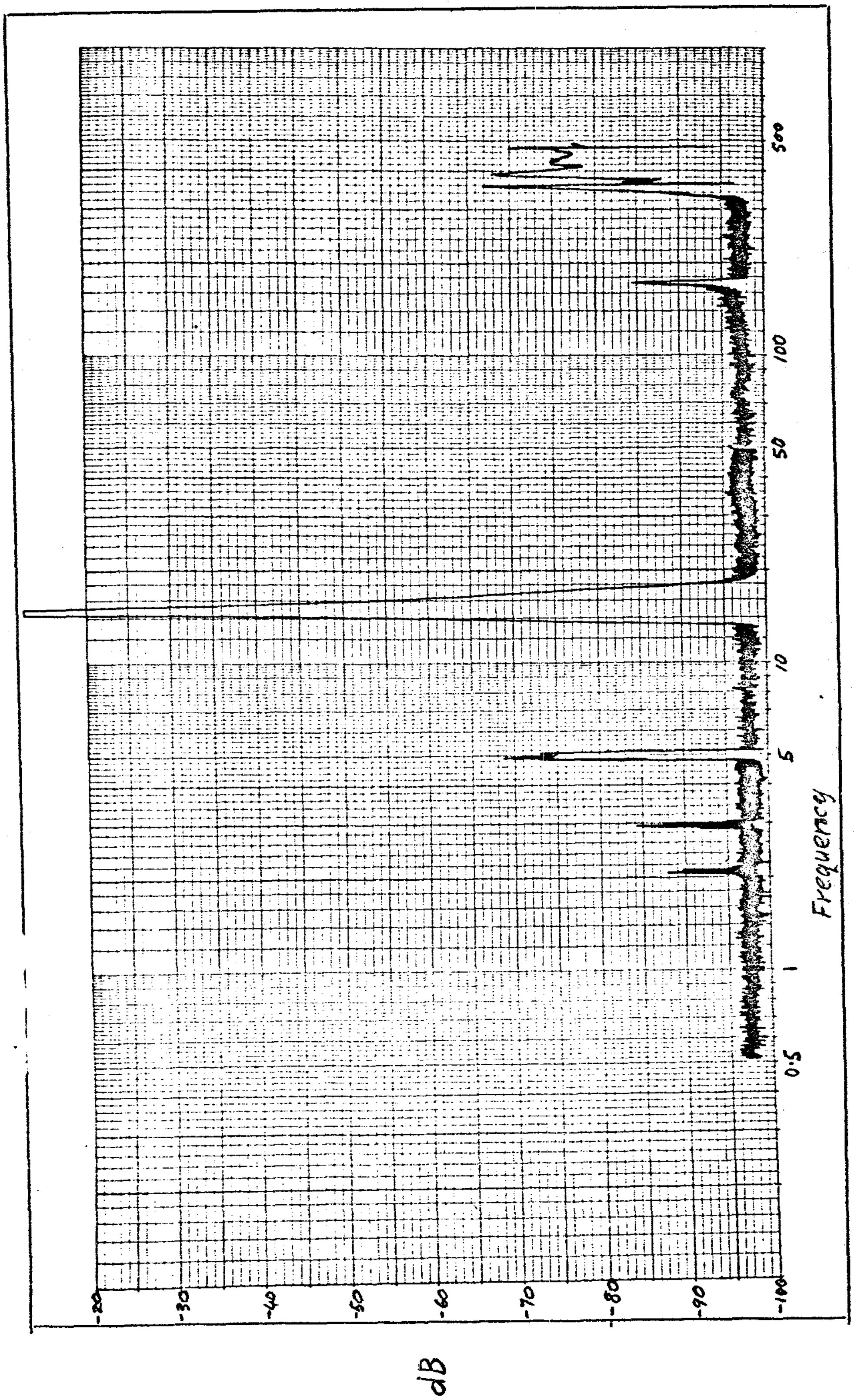


Figure 59. Measured 15 MHz band pass filter insertion loss from 0.5 to 500 MHz (transmitter local oscillator chain)

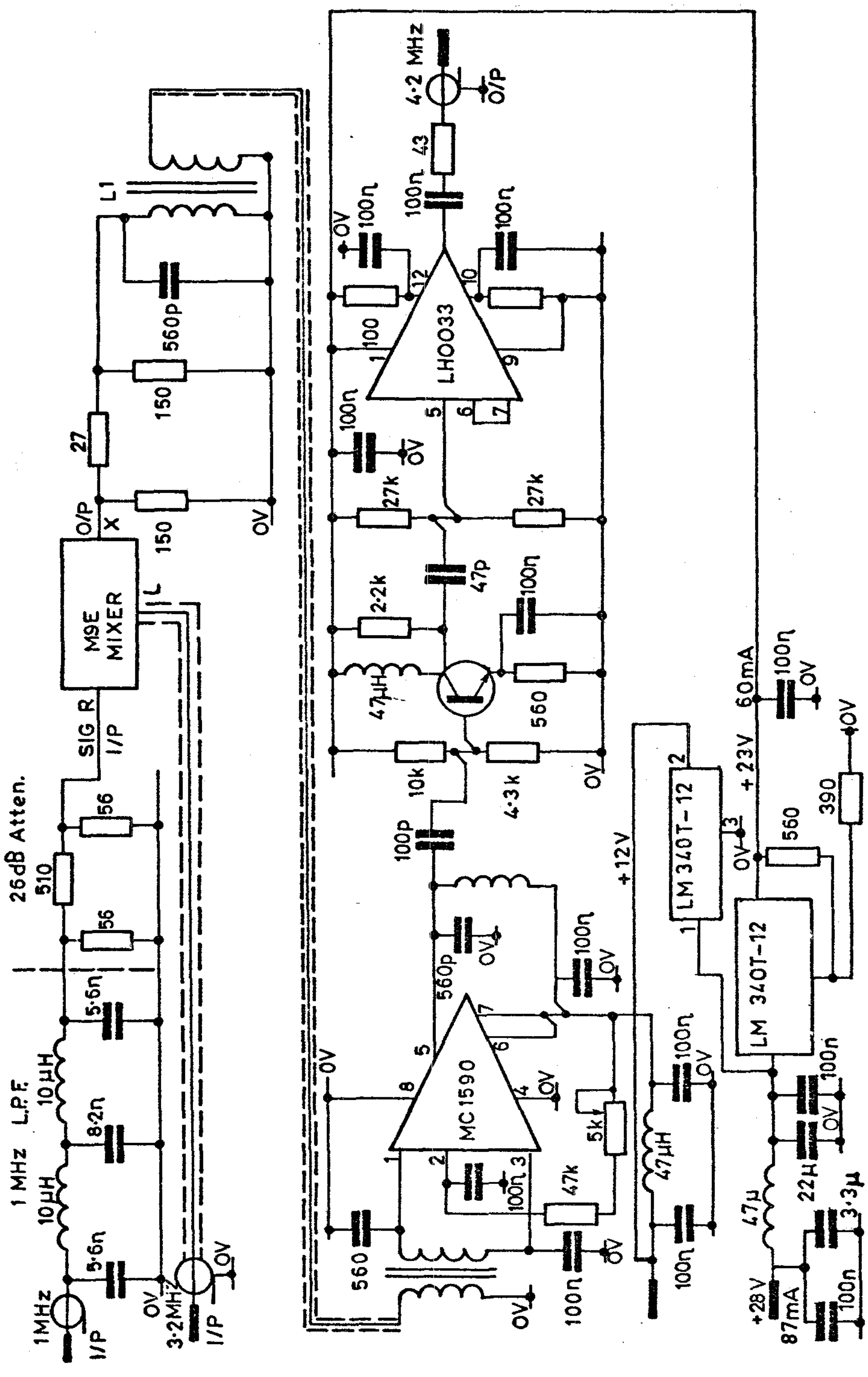


Figure 60. 4.2 MHz mixer amplifier

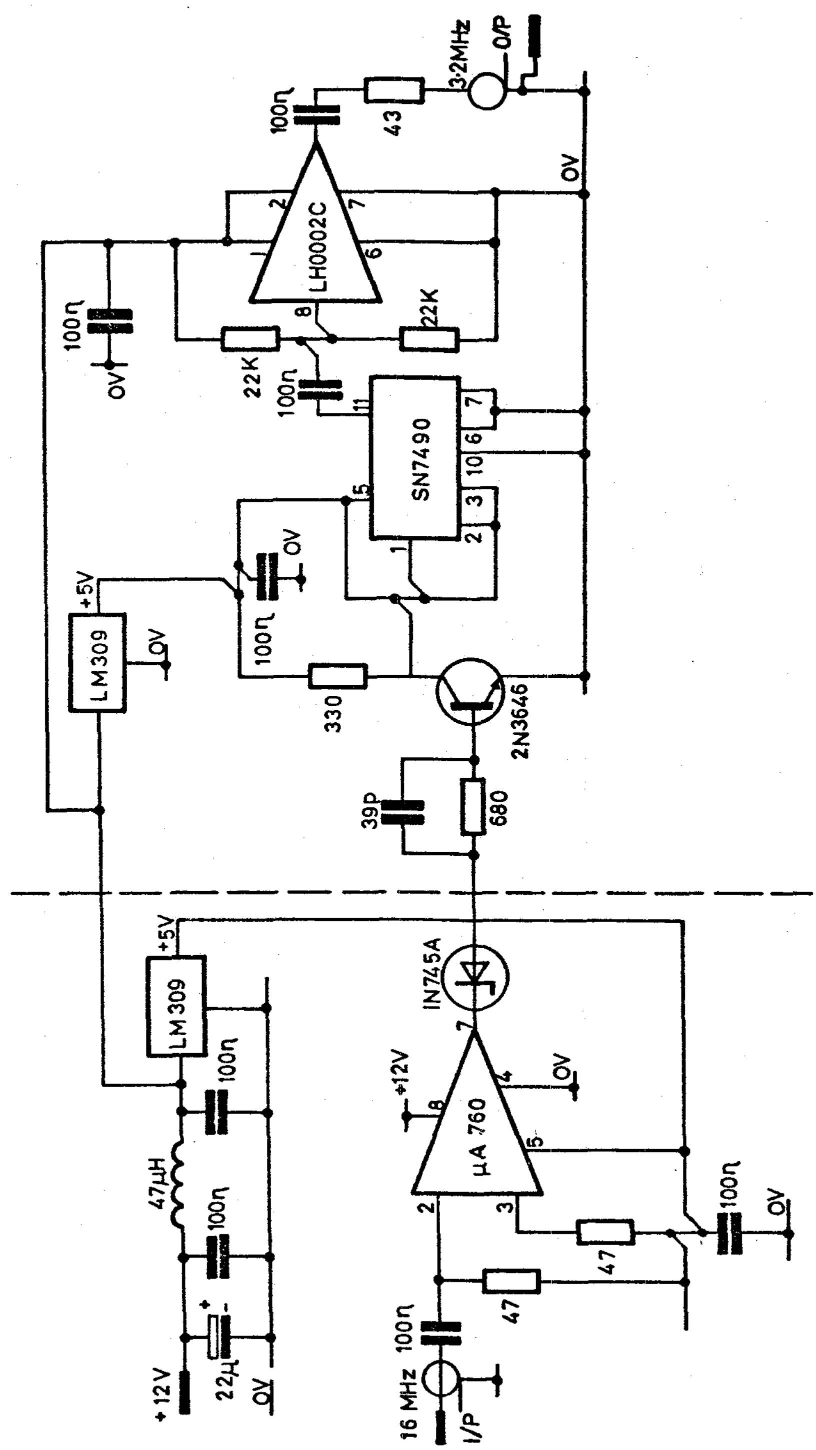


Figure 61. 3.2 MHz generator

RESTRICTED

UNCLASSIFIED

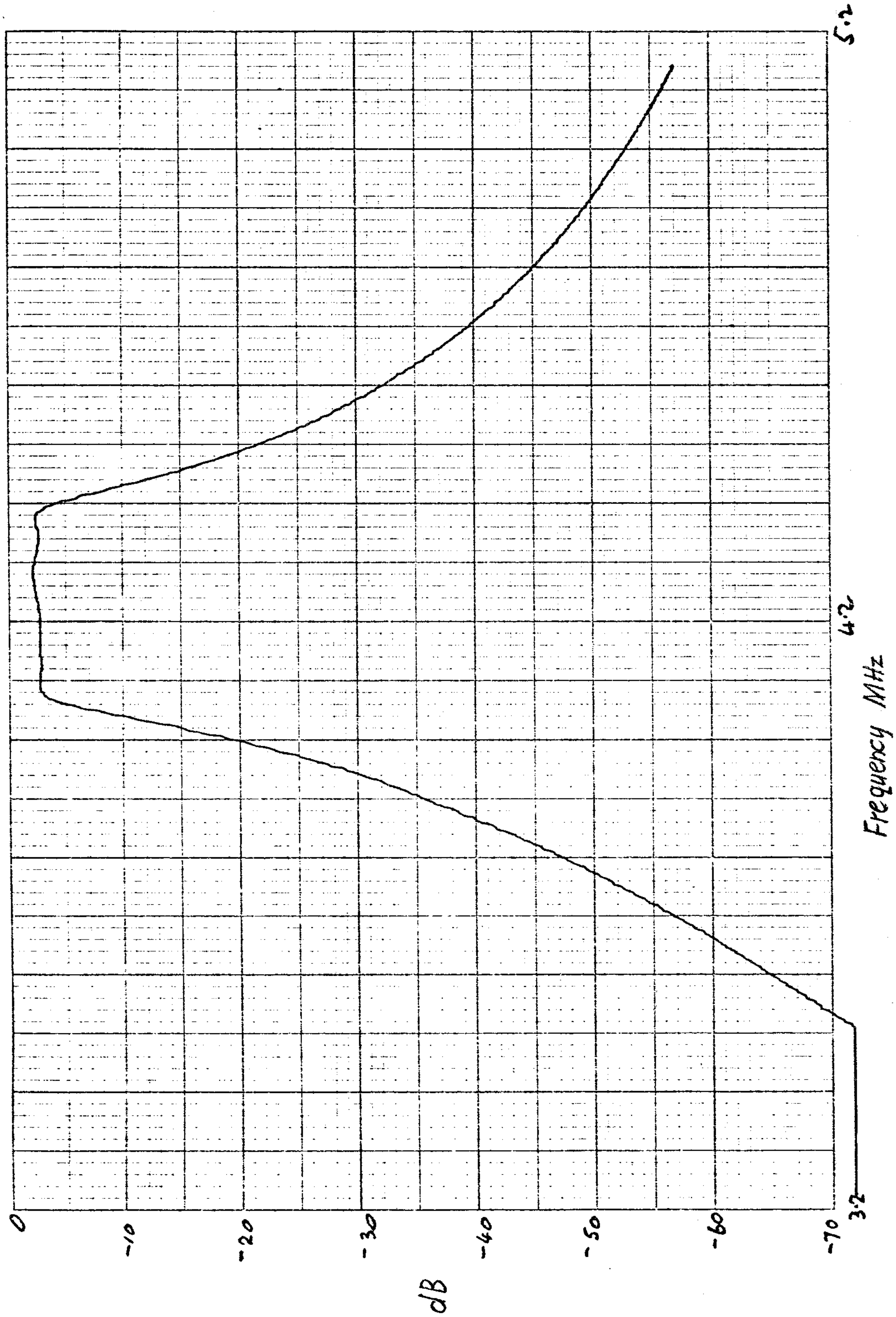


Figure 62. Measured 4.2 MHz band pass filter insertion loss (receiver local oscillator chain)

UNCLASSIFIED

RESTRICTED

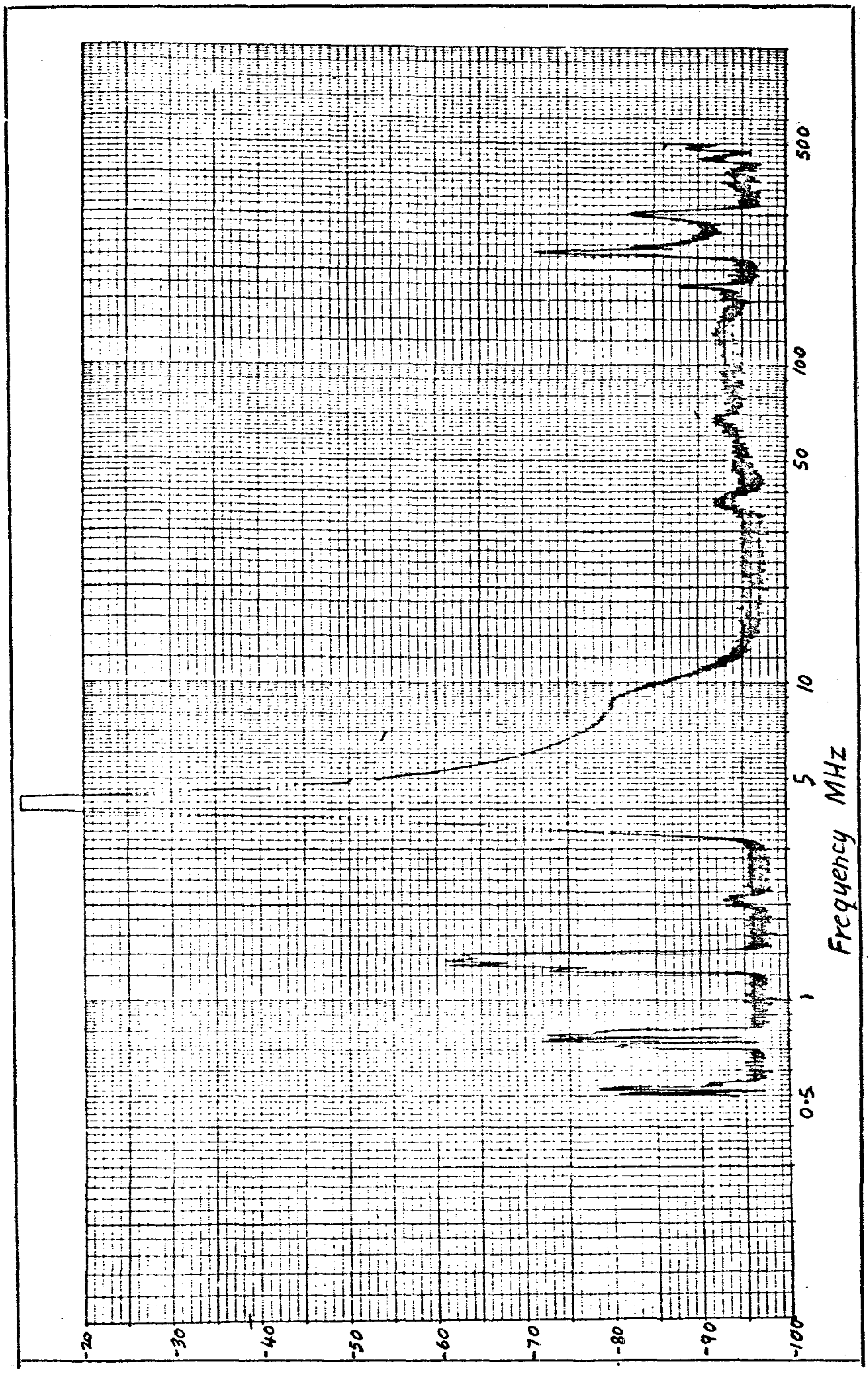
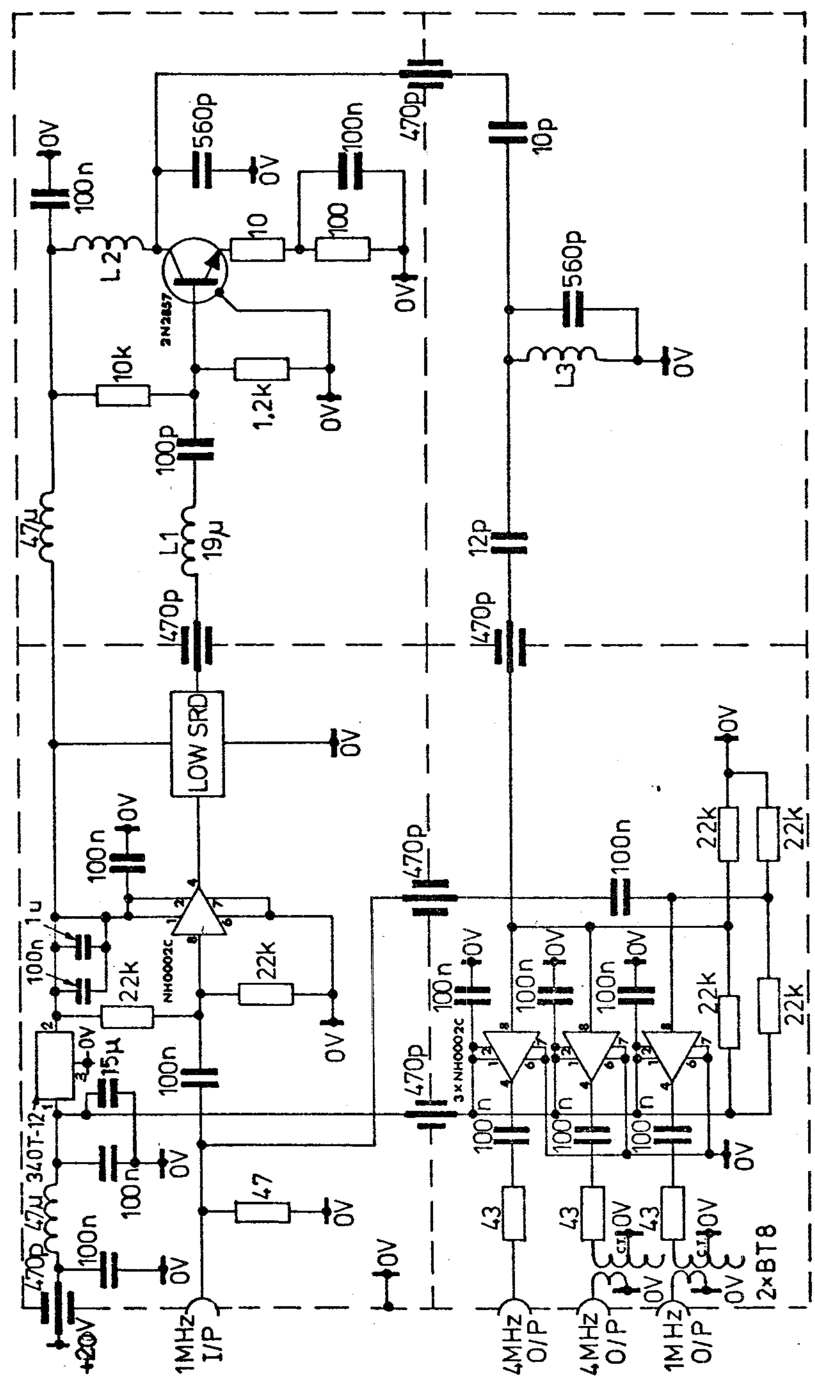


Figure 63. Measured 4.2 MHz band pass filter insertion loss from 0.5 to 500 MHz (receiver local oscillator)



NOTES: L1: 28T 20/44 LIT 2 ON TYPE 'A' NEOSID FORMER WITH TYPE 500 SLUG.
L2,3: 16T 20/44 LIT 2 ON TYPE 'A' NEOSID FORMER WITH TYPE 500 SLUG.

Figure 64. 4 MHz receiver amplifier with multiple outputs

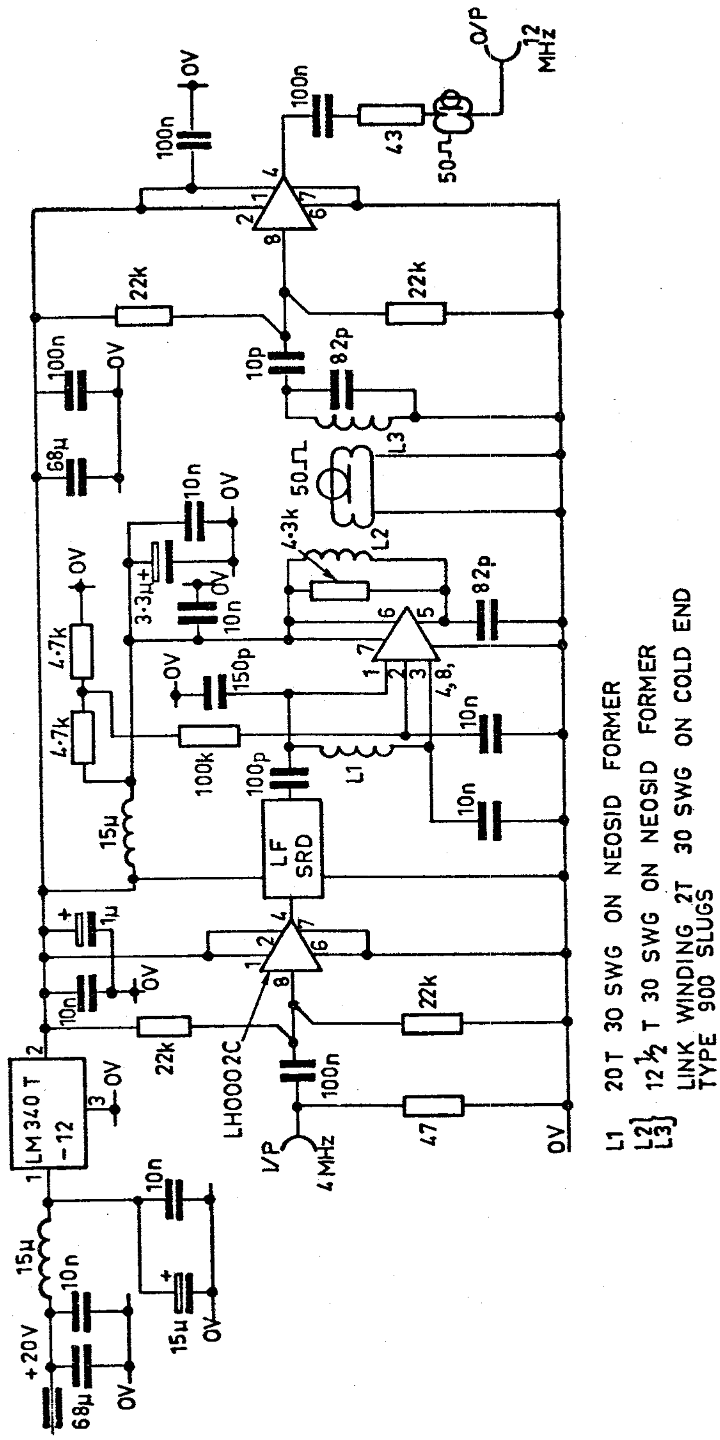
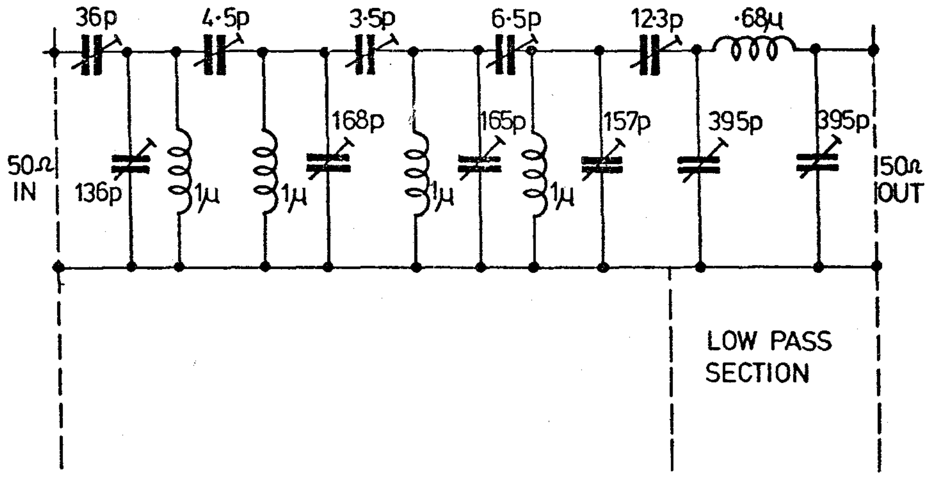


Figure 65. 12 MHz generation local oscillator chain (receiver)



NOTES:

1. INDUCTORS: 1 µH. 9 TURNS 14 GAUGE WIRE 30 MM LONG 22 MM DIAMETER, AIR WOUND.
   0.68 µH. 6 TURNS 14 GAUGE WIRE 16 MM LONG 22 MM DIAMETER, AIR WOUND.

2. FILTER DESIGN DATA: CHEBYSHEV 0.5 dB RIPPLE
   CENTRE FREQUENCY 12 MHz
   BANDWIDTH 0.56 MHz
   UNLOADED INDUCTOR Q = 190
   LOW PASS CUT OFF = 15 MHz

ALIGNMENT OF FILTER
FOR METHOD SEE SECTION 9.4 ZVEREV "HANDBOOK OF FILTER SYNTHESIS"

SECTION	WIDTH (MHz)	LOWER FREQ. (MHz)	UPPER FREQ. (MHz)
WORKING FROM INPUT			
BW OF 1ST	0.38591	11.80704	12.19296
BTWN PEAKS 2ND	0.30503	11.84748	12.15252
OUTER PEAKS 3RD	0.38525	11.80737	12.19262
INNER PEAKS 4TH	0.25604	11.87198	12.12802
OUTER PEAKS 4TH	0.52959	11.73520	12.26479
WORKING FROM OUTPUT			
BW OF 1ST	0.10175	11.94912	12.05088
BTWN PEAKS 2ND	0.44453	11.77774	12.22226
OUTER PEAKS 3RD	0.50297	11.74852	12.25148
INNER PEAKS 4TH	0.25604	11.87198	12.12802
OUTER PEAKS 4TH	0.52959	11.73520	12.26479

Figure 66. 12 MHz band pass filter

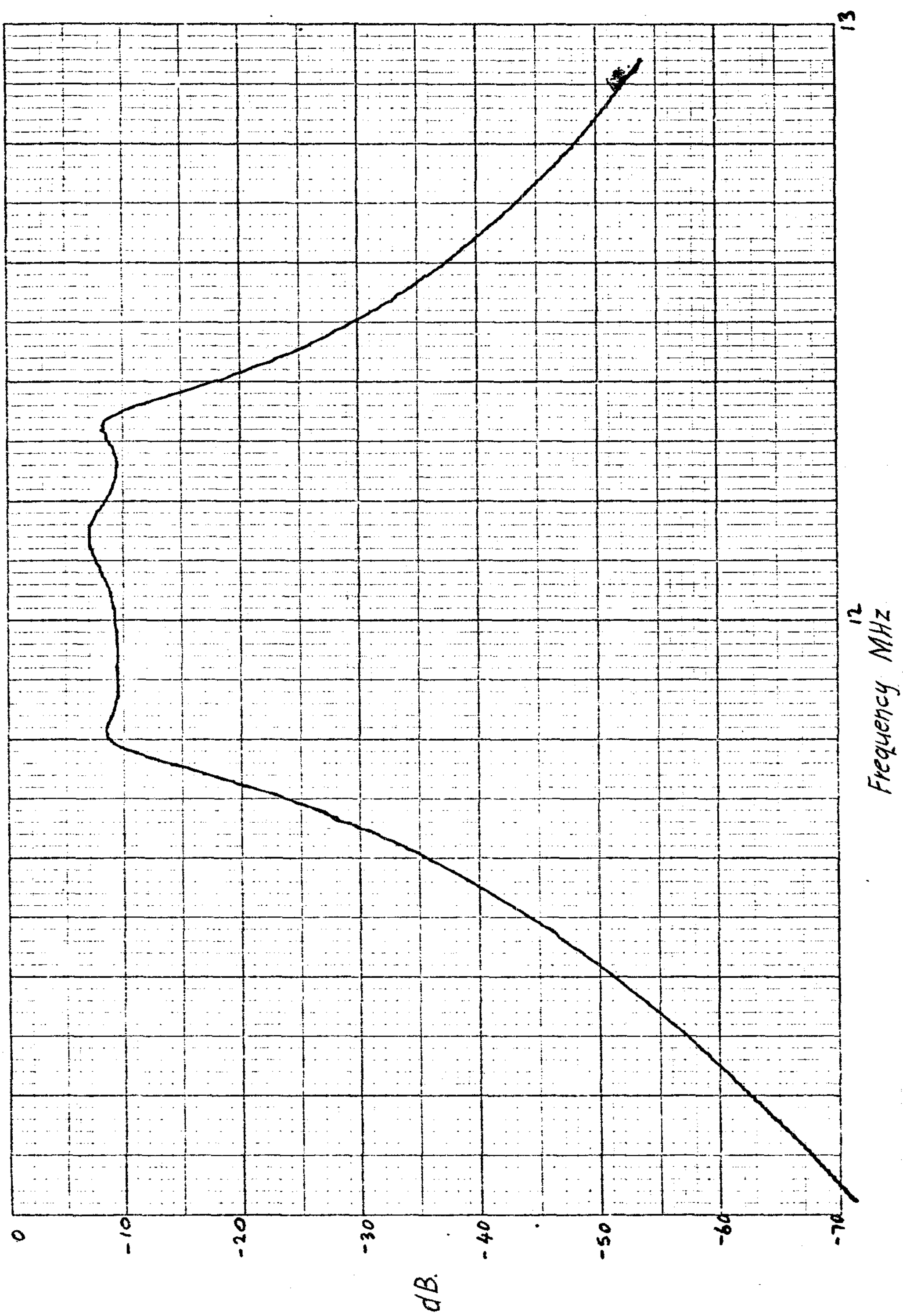


Figure 67. Measured 12 MHz band pass filter insertion loss (receiver local oscillator chain)

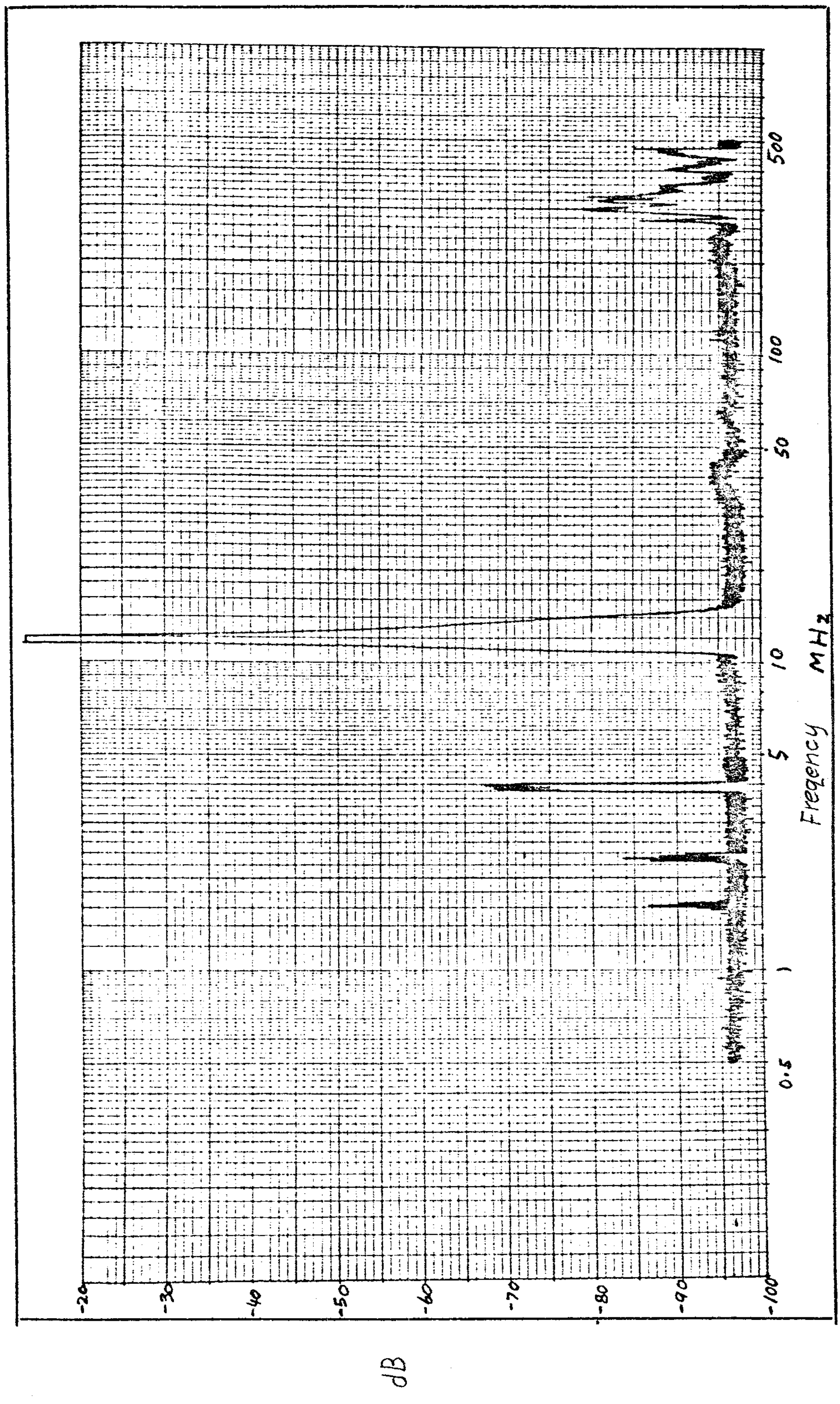
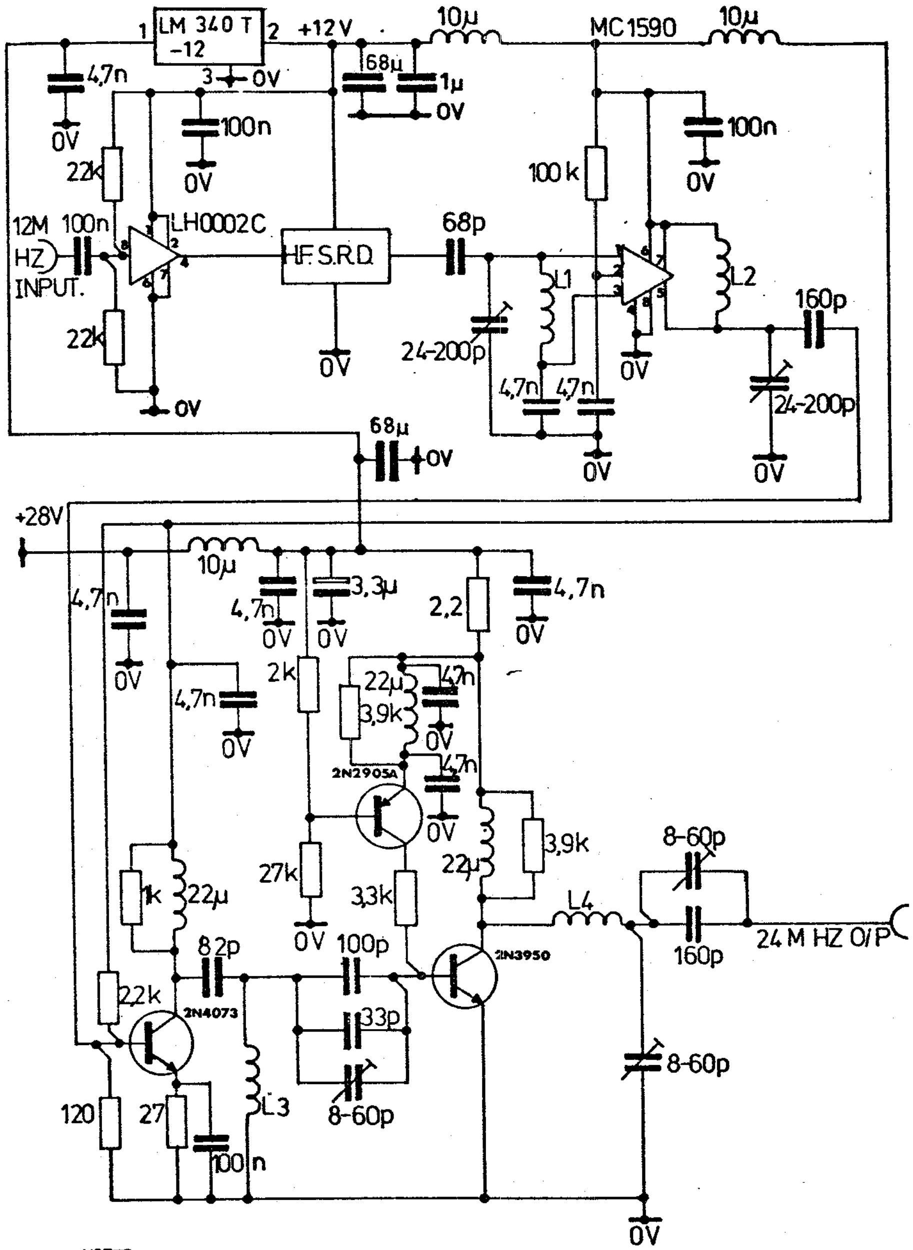


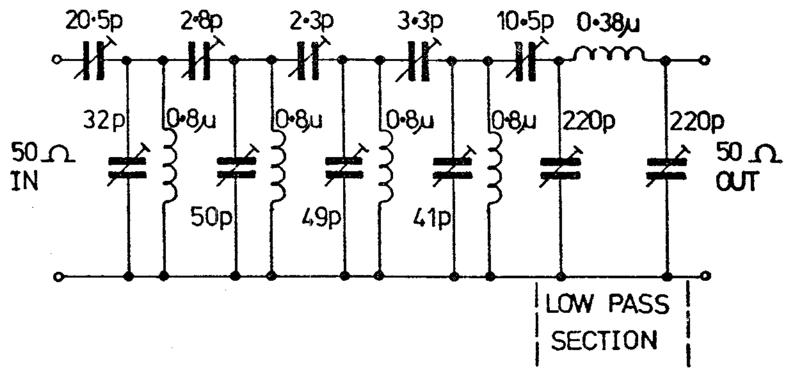
Figure 68. Measured 12 MHz band pass filter insertion loss from 0.5 to 500 MHz (receiver local oscillator chain)



NOTES:

L1 7T 20SWG TCW ON 11MM DIA 15MM LONG
L2 7T 20SWG TCW ON 11MM DIA 13MM LONG
L3 20T 16SWG TCW ON 11MM DIA 15MM LONG
L4 11T 16SWG TCW ON 11MM DIA 27MM LONG

Figure 69. 24 MHz local oscillator driver (receiver)



NOTES:

1. INDUCTORS: 0.8 μH 7 TURNS 14 GAUGE 20 MM LONG 23 MM DIA. AIR WOUND
   0.38 μH 5.5 TURNS 16 GAUGE 14 MM LONG 16 MM DIA. AIR WOUND

2. FILTER DESIGN DATA: CHEBYSHEV 0.5 dB RIPPLE
   CENTRE FREQUENCY = 16 MHz
   BANDWIDTH = 2 MHz
   UNLOADED INDUCTOR Q = 200
   LOW PASS CUT OFF = 27 MHz

ALIGNMENT OF FILTER
FOR METHOD SEE SECTION 9.4 ZVEREV "HANDBOOK OF FILTER SYNTHESIS"

SECTION	WIDTH (MHz)	LOWER FREQ.(MHz)	UPPER FREQ.(MHz)
WORKING FROM INPUT			
BW OF 1ST	1.45043	23.27478	24.72520
BTWN PEAKS 2ND	1.21860	23.39069	24.60930
OUTER PEAKS 3RD	1.56981	23.21509	24.78490
INNER PEAKS 4TH	0.91079	23.54460	24.45538
OUTER PEAKS 4TH	1.92451	23.03773	24.96225
WORKING FROM OUTPUT			
BW OF 1ST	0.48365	23.75816	24.24182
BTWN PEAKS 2ND	1.43840	23.28079	24.71919
OUTER PEAKS 3RD	1.74594	23.12703	24.87296
INNER PEAKS 4TH	0.91079	23.54460	24.45538
OUTER PEAKS 4TH	1.92451	23.03773	24.96225

Figure 70. 24 MHz band pass filter

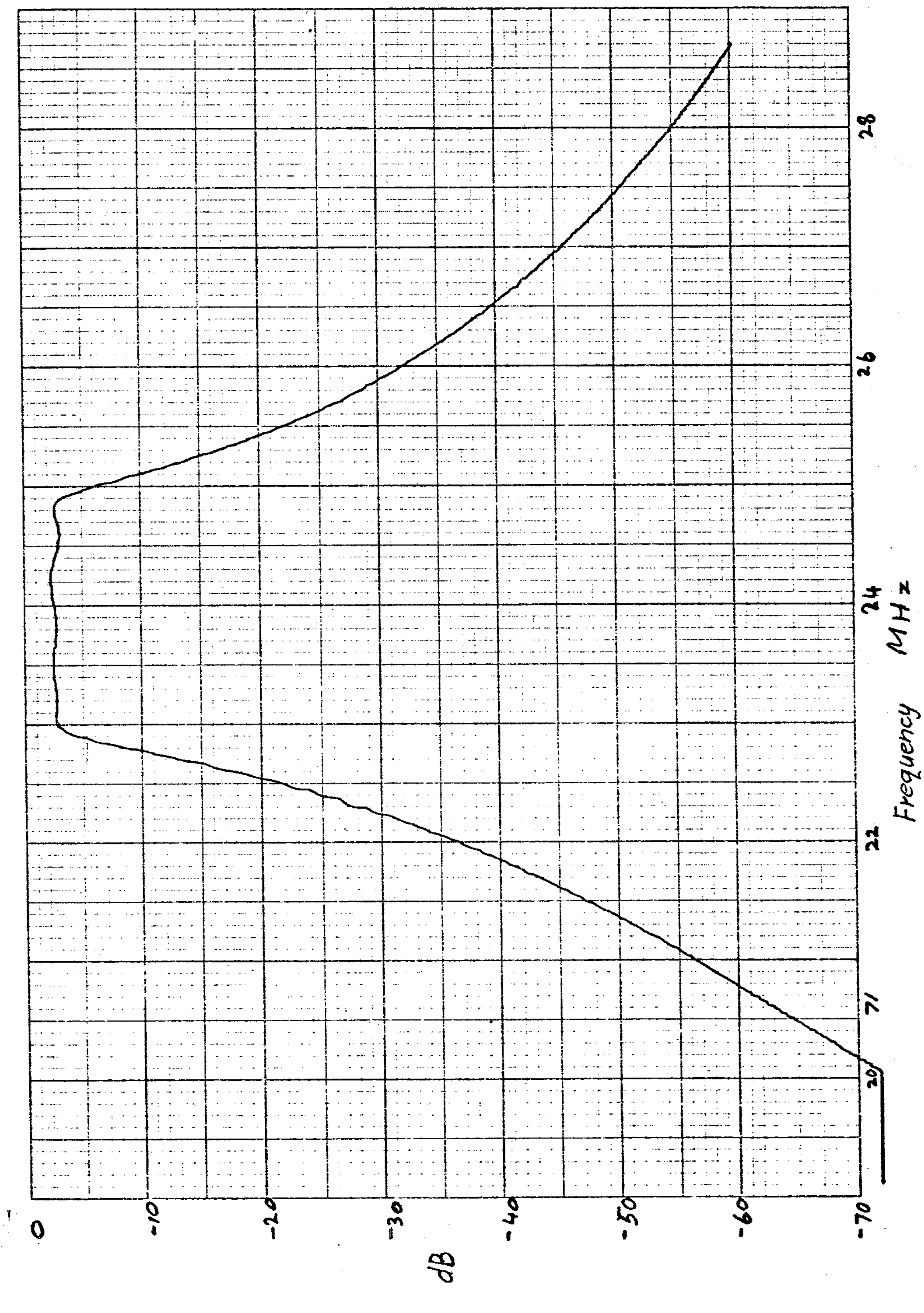


Figure 71. Measured 24 MHz band pass filter insertion loss (receiver local oscillator chain)

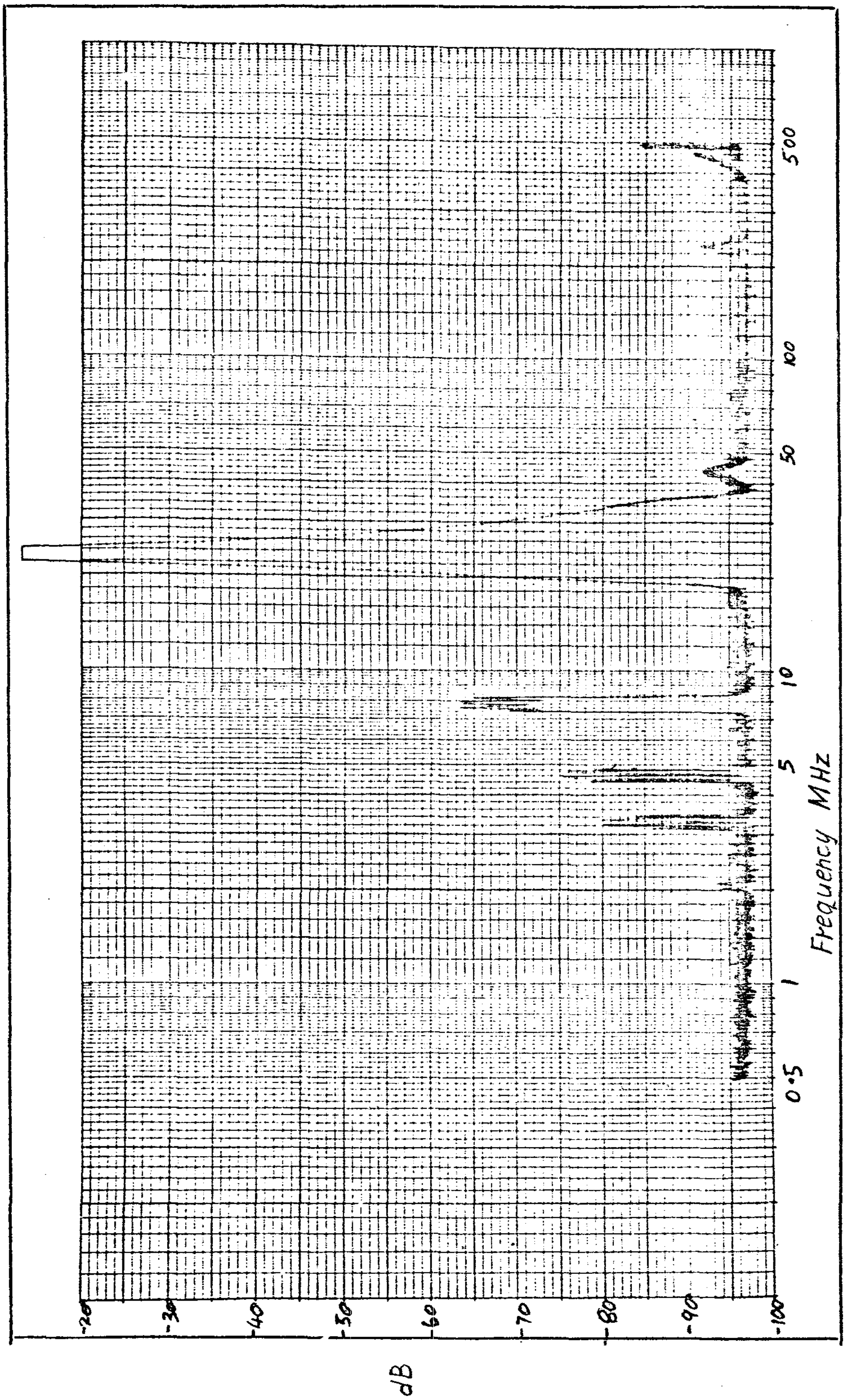


Figure 72. Measured 24 MHz band pass filter insertion loss from 0.5 to 500 MHz (receiver local oscillator chain)

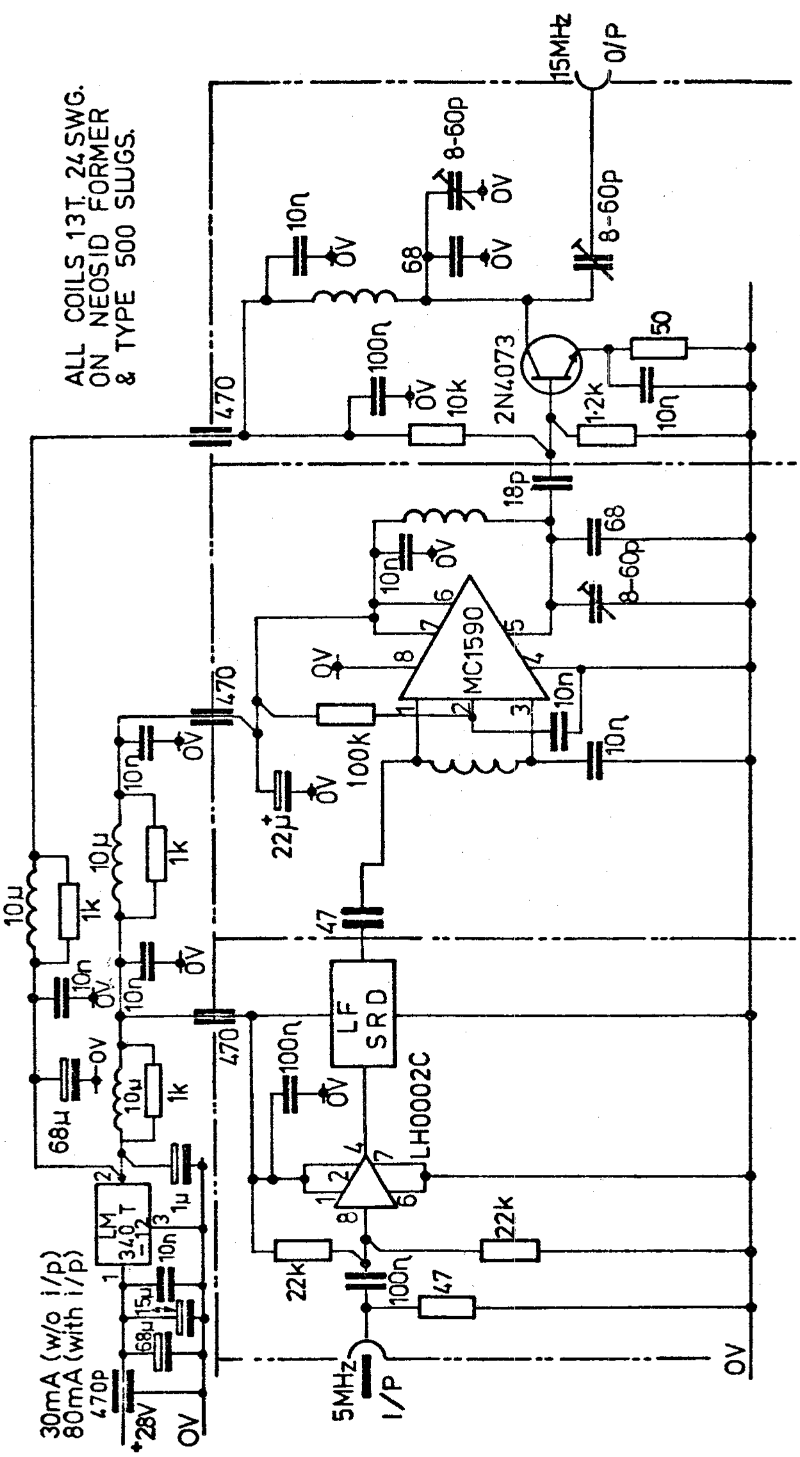


Figure 73. 15 MHz amplifier receiver local oscillator chain

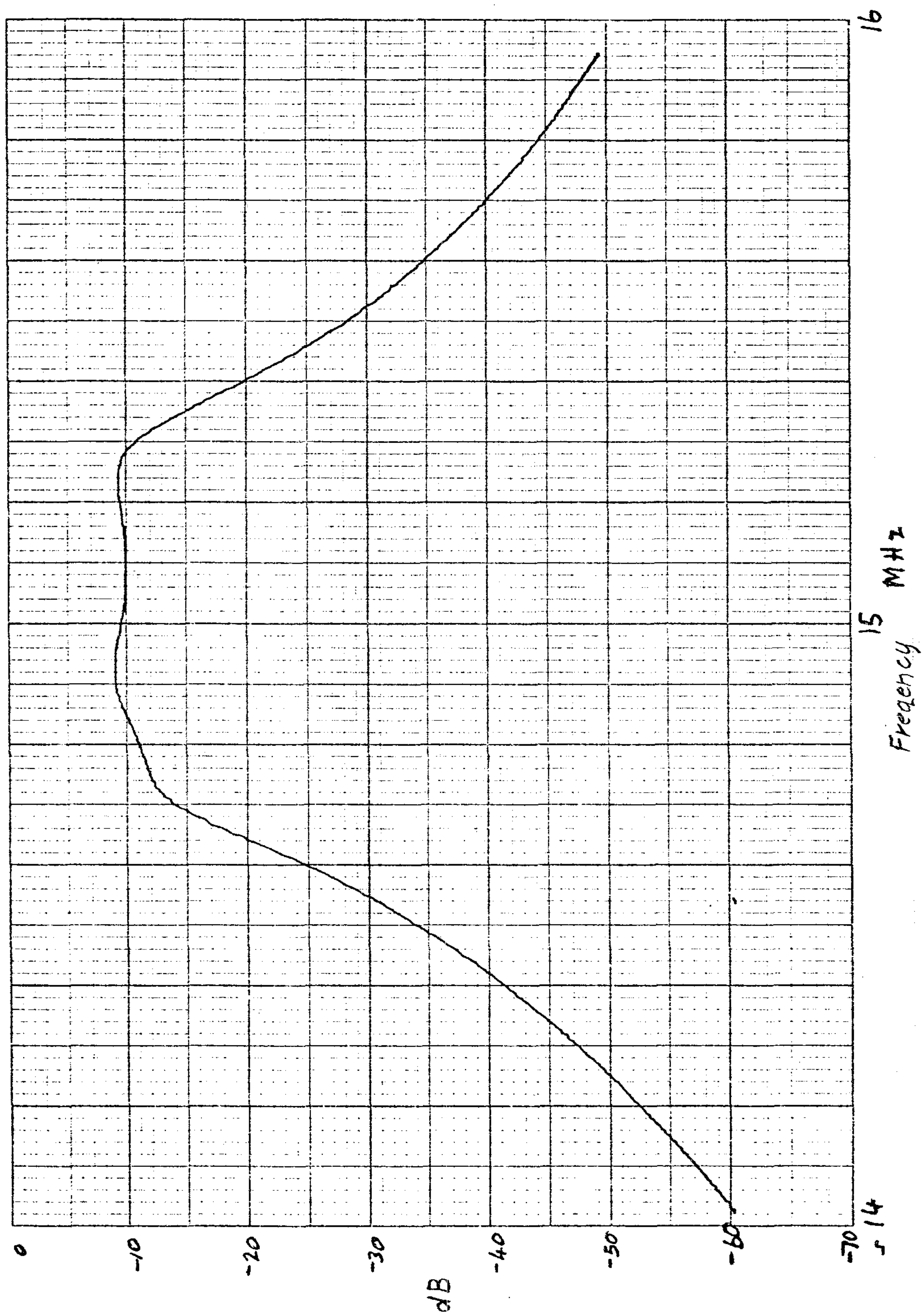


Figure 74. Measured 15 MHz band pass filter insertion loss (receiver local oscillator chain)

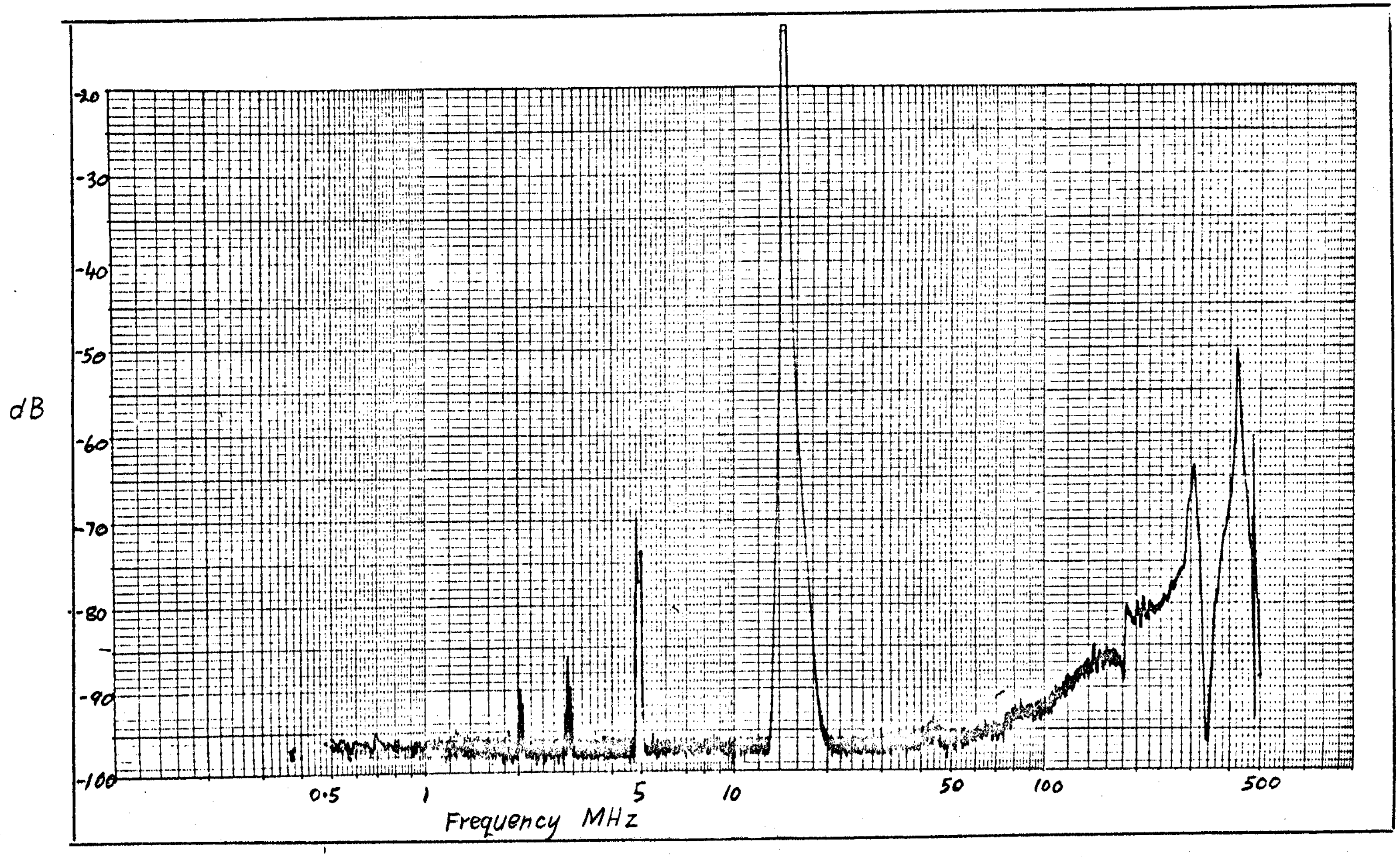


Figure 75. Measured 15 MHz band pass filter insertion loss from 0.5 to 500 MHz (receiver local oscillator chain)

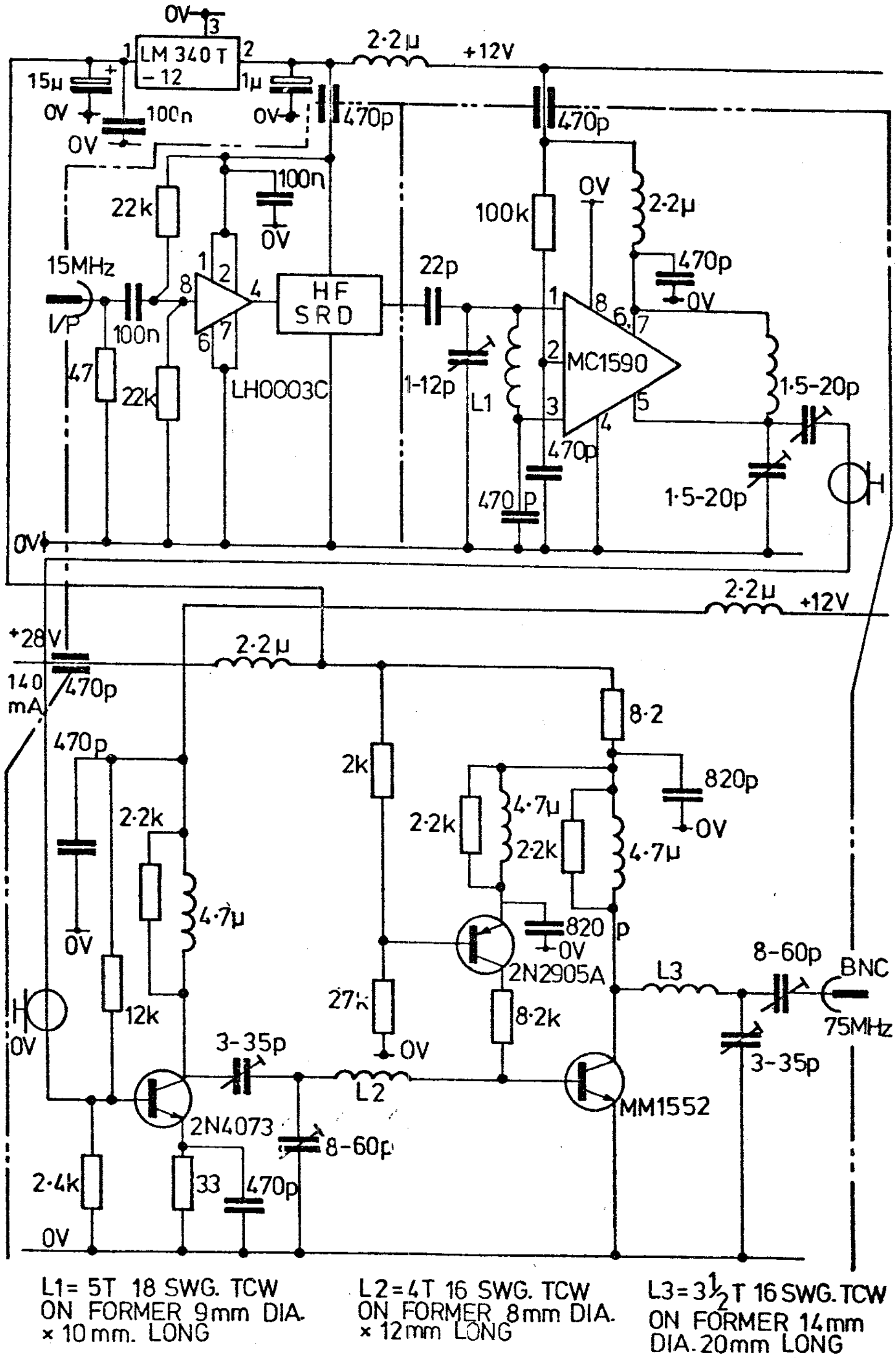


Figure 76. 75 MHz amplifier (receiver local oscillator chain)

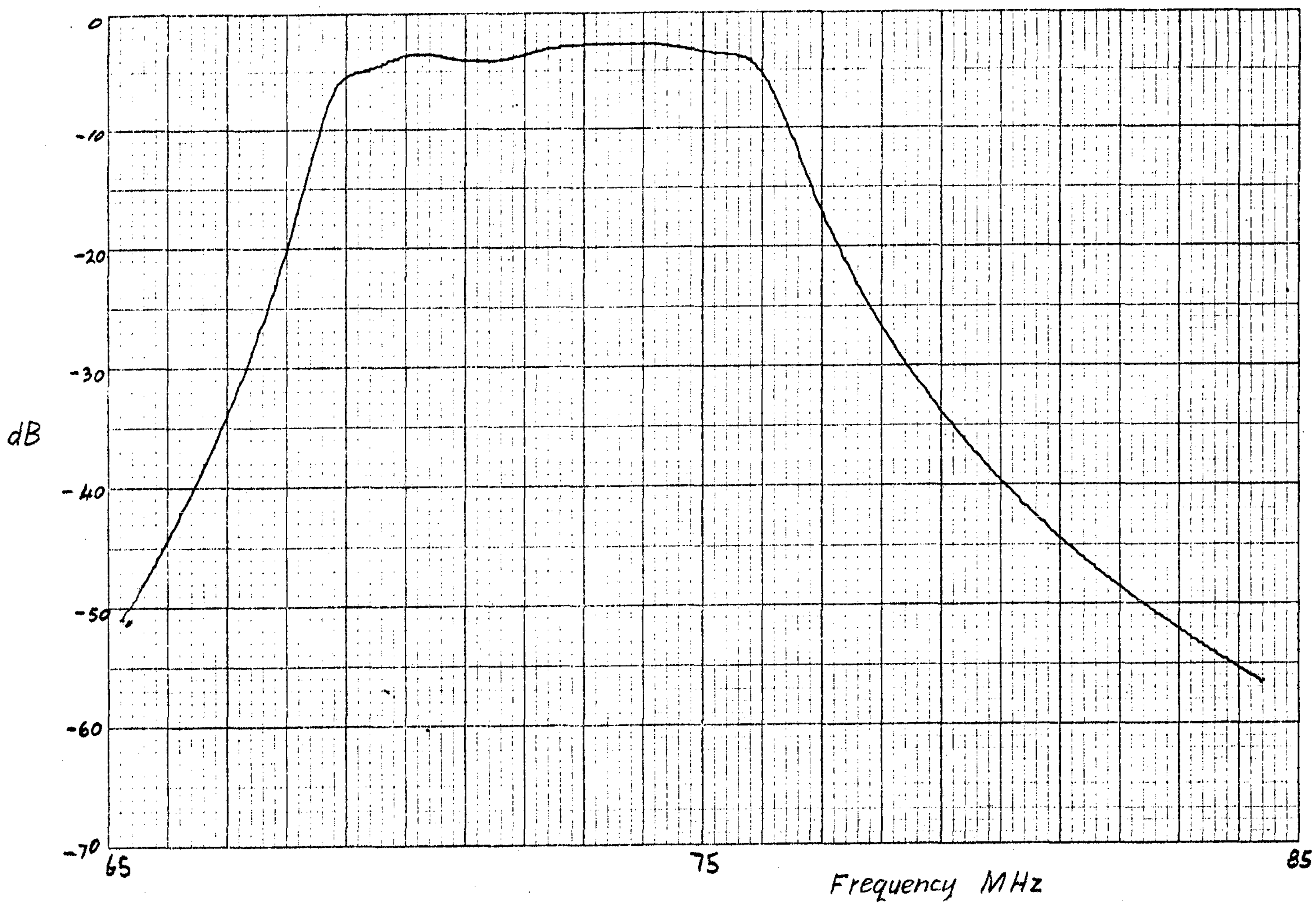


Figure 77. Measured 75 MHz band pass filter insertion loss (receiver local oscillator chain)

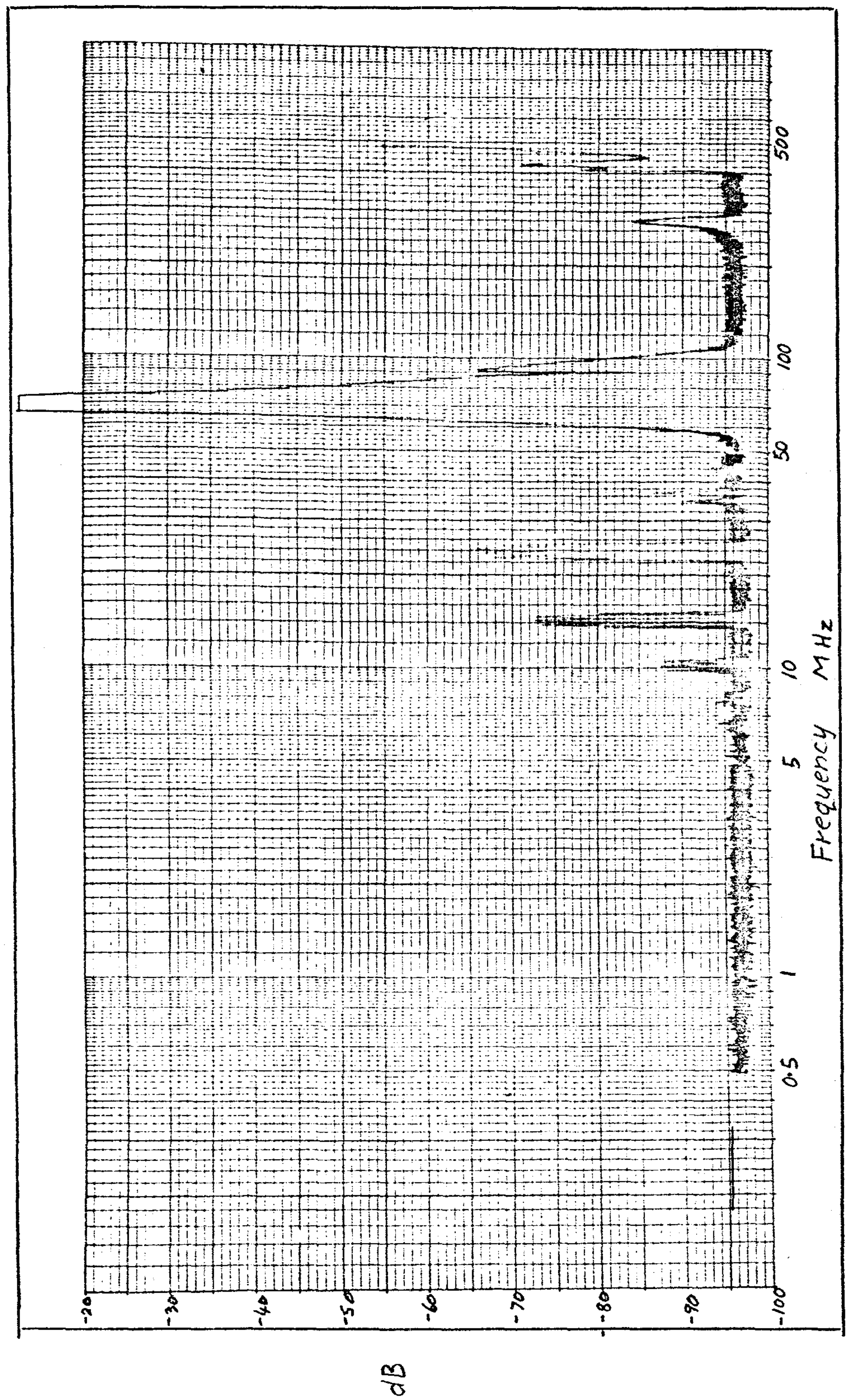
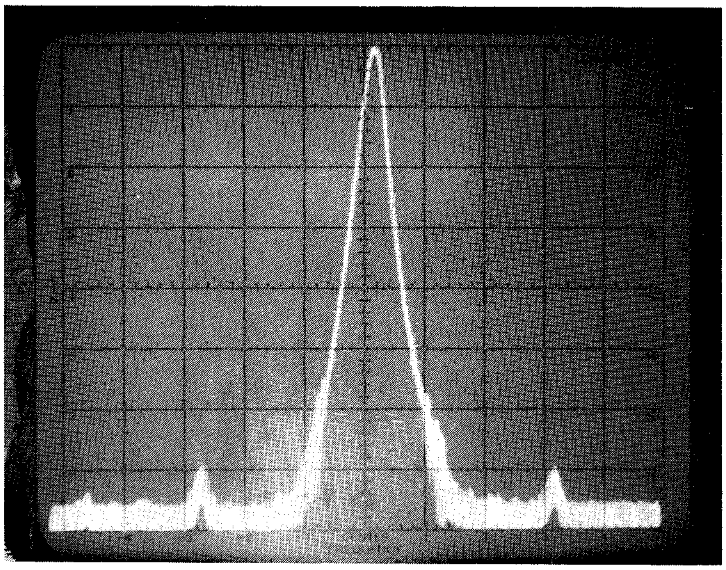


Figure 78. Measured 75 MHz band pass filter insertion loss from 0.5 to 500 MHz (receiver local oscillator chain)

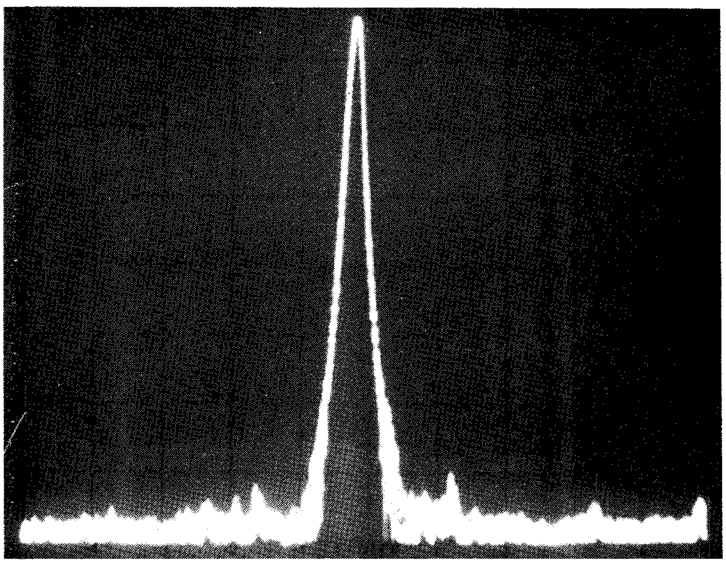


Spectrum Analyser Settings:

Centre Frequency	25 MHz
Bandwidth	10 Hz
Sweep Width	50 Hz/div
Scan Time	1 sec/div
Video Filter	Off

Date: 26.3.76

(a)



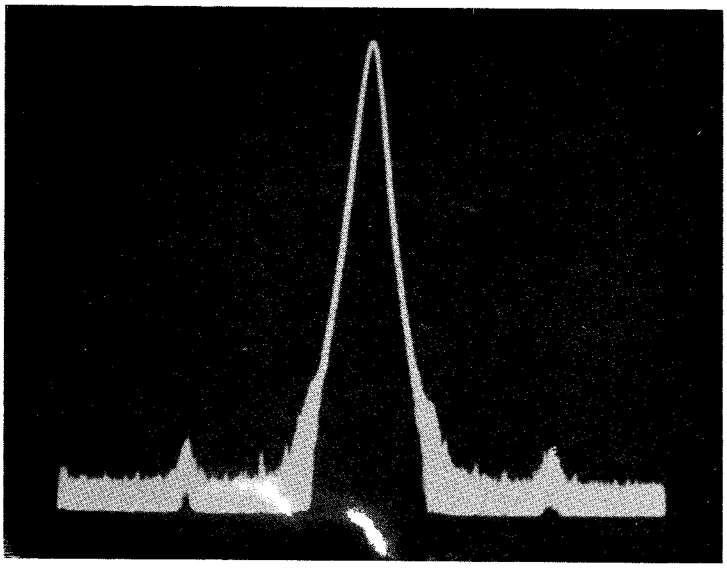
Spectrum Analyser Settings:

Centre Frequency	18 MHz
Bandwidth	0.01 kHz
Sweep Width	100 Hz/div
Scan Time	2 sec
Video Filter	Off

Date: 5.6.77

(b)

Figure 79. Spectrum of a CW signal at the output of the translator



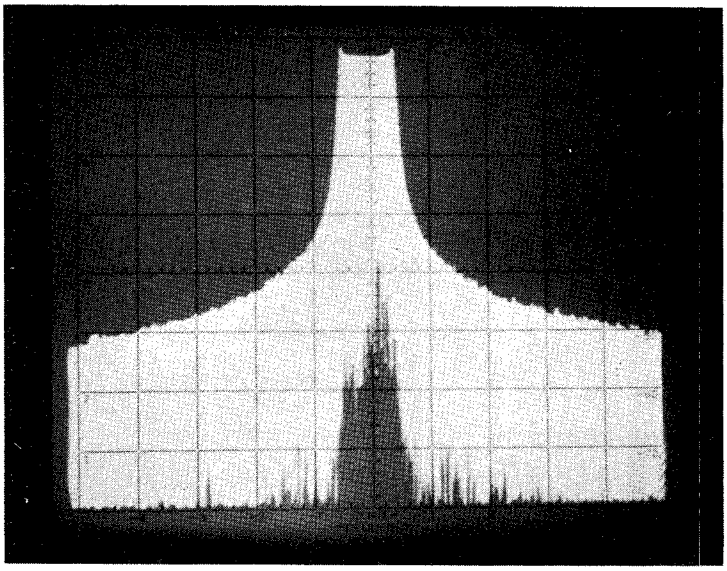
Notes on conditions of measurement:

1. HP105B Standard Frequency Oscillator, on internal batteries, in a screened room.
2. Measurement made with an HP141T series spectrum analyser.
3. No other instruments were in operation and care was taken to avoid earth loops.

Spectrum Analyser Settings:

Centre Frequency	5.0 MHz
Bandwidth	10 Hz
Scan Width	50 Hz/div
Scan Time	1 sec/div
Video Filter	Off

Figure 80. Display of the spectrum of a standard oscillator output by HP141T series spectrum analyser



Spectrum Analyser Settings:

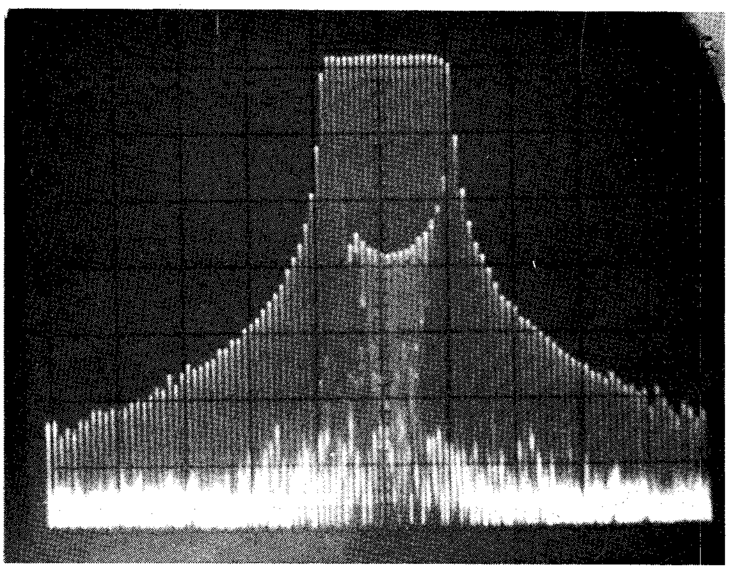
Centre Frequency	10.7 MHz
Bandwidth	0.1 kHz
Sweep Width	10 kHz/div
Scan Time	2 sec/div
Video Filter	Off

Sweep Parameters:

Manual Mode
500 kHz/s
50 Hz repetition rate

Date: 9.7.76

(a)



Spectrum Analyser Settings:

Bandwidth	0.3 kHz
Sweep Width	10 kHz/div
Scan Time	0.2 sec
Video Filter	Off

Sweep Parameters:

Manual Mode
1 MHz/s

Date: 22.2.77

(b)

Figure 81. Examples of the spectrum of linear FM waveform taken at the output of the translator

```
PARAME  'S
J= 400
K=  50
PRF= 50.00HZ
FREQ=10700  -2500HZ
SWEEP RATE= 500KHZ/SEC
DELAY= 5000MICROSEC
BW=10000.00
 -75 -83 -82 -86 -85 -81 -87 -76 -79 -73 -74 -73 -82 -81 -73     -73 -75 -77 -75 -94 -73 -85 -82 -75 -78 -80 -78 -85 -85 -87
 -74 -82 -75 -78 -79 -78 -76 -77 -82 -90 -88 -81 -77 -83 -92     -69 -80 -72 -76 -74 -81 -84 -93 -82 -79 -89 -98 -77 -76 -93
 -86 -71 -76 -83 -73 -70 -71 -79 -95 -84 -79 -74 -85 -77-102     -70 -72 -72 -71 -71 -87 -75 -80 -81 -78 -85 -77 -73 -69 -74
 -80 -96 -77 -80 -82 -78 -73 -77 -74 -86 -82 -73 -84 -84 -77     -72 -73 -74 -76 -84 -82 -80 -82 -92 -80 -74 -73 -81 -80 -95
 -77 -80 -74 -76 -81 -89 -73 -73 -70 -75 -84 -76 -79 -93 -72     -78 -75 -72 -75 -80 -73-100 -77 -76 -76 -75 -72 -79 -79 -84
 -77 -94 -73 -74 -73 -75 -88 -88 -80 -81 -80 -84 -80 -78 -85     -79 -67 -79 -75 -73 -92 -79 -83 -91 -90 -84 -82 -92 -91 -81
 -80 -81 -72 -76 -78 -89 -86 -78 -79 -80 -85 -94 -82 -74 -83     -71 -76 -77 -78 -75 -85 -79 -78 -79 -77 -76 -78 -79 -83 -78
 -73 -89 -95 -77 -79 -85 -83 -78 -72 -75 -76 -96 -72 -78 -73     -74 -75 -73 -72 -87 -75 -77 -78 -74 -79 -75 -74 -81 -75 -72
 -78 -80 -95 -87 -77 -80 -84-102 -78 -79 -72 -75 -81 -77 -82     -71 -70 -79 -74 -78 -84 -75 -77 -76 -77 -82 -77 -80 -79 -76
 -77 -71 -75 -74 -84 -78 -83 -79 -78 -84 -90 -76 -76 -90 -75     -76 -70 -82 -74 -84 -73 -80 -80 -79 -86 -84 -81 -75 -84 -82
 -82 -94 -83 -77 -83 -88 -75 -73 -79 -92 -78 -80 -74 -79 -92     -73 -78 -77 -84 -71 -79 -78 -78 -83 -93 -91 -74 -73 -77 -85
 -82 -89 -80 -76 -83 -87 -79 -78 -84 -80 -77 -97 -85 -76 -74     -71 -73 -82 -73 -74 -78 -75 -80 -81 -79 -77 -70 -84 -80 -83
 -74 -81 -86 -83 -84 -81 -78 -71 -73 -82 -82 -83 -75 -75 -69     -72 -78 -74 -76 -80 -71 -88 -80 -92 -92 -80 -72 -73 -77 -83
 -78 -76 -87 -82 -82 -85 -85 -76 -79 -78 -83 -83 -74 -81 -75     -66 -65 -77 -75 -77 -73 -85 -77 -98 -83 -74 -85 -87 -79 -88
 -89 -76 -80 -75 -76 -85 -80 -83 -77 -75 -73 -76 -80 -80 -80     -72 -73 -84 -73 -84 -74 -82 -86 -78 -79 -78 -76 -81 -81 -80
 -90 -81 -76 -76 -74 -75 -78 -75 -88 -80 -77 -72 -71 -86 -77     -77 -68 -77 -74 -79 -74 -77 -71 -76 -77 -79 -81 -75 -75 -71
 -73 -81 -84 -81 -83 -91 -81 -78 -78 -77 -80 -82 -73 -75 -70     -70 -70 -77 -70 -74 -71 -79 -77 -84 -84 -82 -85 -85 -94 -93
 -74 -77 -76 -75 -75 -72 -77 -75 -72 -73 -72 -78 -74 -85 -75     -69 -91 -72 -71 -72 -72 -78 -70 -77 -77 -72 -75 -75 -77 -75
 -77 -71 -80 -82 -83 -88 -75 -76 -75 -90 -96 -78 -76 -76 -78     -76 -69 -84 -73 -80 -86 -73 -83 -78 -82 -84 -74 -75 -73 -86
 -80 -74 -77 -96 -77 -83 -79 -83 -77 -75 -74 -83 -96 -72 -77     -71 -72 -83 -73 -77 -81 -78 -75 -75 -74 -75 -84 -80 -80 -80
 -83 -76 -74 -77 -86 -79 -81 -84 -81 -83 -79 -80 -78 -81 -76     -71 -77 -73 -80 -86 -77 -81 -74 -96 -81 -75 -85 -93 -82 -78
 -73 -82 -80 -81 -75 -84 -84 -74 -77 -83 -75 -86 -83 -81 -72     -71 -69 -83 -70 -76 -85 -74 -84 -84 -76 -75 -77 -89 -77 -78
 -86 -81 -90 -77 -91 -85 -90 -76 -81 -73 -75 -70 -83 -96 -97     -68 -87 -69 -77 -71 -91 -77 -76 -73 -78 -75 -81 -83 -77 -93
 -79 -72 -71 -73 -80 -71 -72 -75 -72 -75 -85 -70 -76 -74 -79     -77 -70 -70 -70 -81 -81 -77 -80 -78 -72 -74 -76 -77 -71 -77
 -76 -79 -76 -79 -79 -75 -76 -76 -80 -77 -73 -74 -71 -73 -71     -75 -72 -81 -76 -79 -71 -78 -74 -73 -75 -79 -81 -78 -77 -74
 -93 -73 -80 -79 -76 -75 -73 -88 -74 -73 -75 -89 -87 -71 -74     -71 -71 -88 -93 -98 -72 -78 -78 -65 -71 -77 -85 -90 -71 -73
 -80 -75 -80 -82 -83 -79 -78 -98 -85 -75 -86 -81 -75 -76 -72     -72 -69 -72 -90 -70 -73 -83 -73 -81 -82 -84 -78 -94 -77 -79
 -82 -76 -76 -81 -86 -81 -82 -79 -85 -76 -83 -79 -77 -73 -76     -74 -73 -75 -87 -73 -71 -74 -84 -78 -82 -73 -75 -74-108 -84
 -86 -82 -87 -79 -79 -81 -76 -81 -86 -81 -88 -93 -85 -81 -72     -82 -71 -78 -78 -82 -79 -80 -85 -79 -83 -86 -74 -72 -81 -80
 -75 -77-105 -99 -79 -79 -81 -85 -79-101 -80 -77 -72 -89 -81     -76 -76 -75 -77 -74 -83 -80 -72 -78 -77 -74 -77 -76 -87 -87
 -75 -79 -81 -90 -77 -87 -79 -73 -77 -80 -72 -70 -68 -73 -74     -72 -90 -71 -73 -84 -72 -73 -68 -78 -79 -80 -79 -77 -99 -80
 -72 -73 -81 -83 -66 -66 -67 -69 -78 -74 -78 -65 -75 -68 -74     -70 -65 -71 -68 -74 -80 -72 -68 -65 -73 -87 -71 -69 -66 -67
 -75 -79 -85 -79 -79 -78 -91 -80 -72 -77 -82 -79 -71 -77 -91     -90 -73 -77 -70 -79 -77 -76 -71 -70 -71 -72 -70 -82 -80 -73
 -79 -81 -75 -84 -82 -78 -73 -83 -76 -82 -76 -74 -91 -72 -83     -80 -75 -73 -81 -71 -77 -75 -91 -73 -87 -90 -80 -75 -74 -75
 -91 -83 -75 -77 -86 -80 -84 -79 -87 -79 -79 -75 -72-101 -84     -67 -85 -71 -74 -79 -77 -75 -72 -83 -90 -83 -78 -80 -82 -78
 -77 -76 -86 -88 -75 -79 -84 -83 -78 -82 -73 -80 -80 -73 -72     -69 -71 -75 -73 -69 -76-101 -74 -77 -75 -78 -90 -85 -81 -74
 -83 -80 -79 -82 -73 -81 -79 -74 -79 -91 -81 -80 -79 -76 -75     -78 -89 -74 -75 -72 -91 -84 -87 -81 -76 -75 -71 -79 -77 -94
 -72 -73 -74 -92 -82 -74 -85 -84 -87 -73 -72 -82 -72 -76 -76     -68 -72 -75 -72 -87 -71 -77 -73 -78 -83 -74 -74 -76 -82 -75
 -77 -84 -86 -97 -89 -83 -87 -82 -83 -75 -79 -86 -77 -83 -78     -75 -73 -85 -75 -84 -81 -78 -77 -78 -75 -82 -73 -76 -76 -83
 -74 -75 -77 -75 -96 -78 -85 -78 -79 -83 -80 -77 -74 -76 -78     -67 -71 -72 -91 -74 -75 -91 -80 -85 -80 -90 -79 -79 -89 -77
 DBS     -51 -52 -53 -54 -55 -56 -57 -58 -59 -60 -61 -62 -63 -64 -65 -66 -67 -68 -69 -70 -71 -72 -73 -74 -75 -76 -77 -78 -79 -80
HISTLO     0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   2   1   2   2   0  12  26  26  28  47 [illegible] [illegible] 25 [illegible] [illegible]
HISTHI     0   0   0   0   0   0   0   0   0   0   0   0   0   0   2   2   4   8  10  16  34  31  40  38  45  36  51  44  32 [illegible]
```

Figure 82. Computer printout of noise floor levels in specified segments of the deramped signal spectrum (50 Hz case)

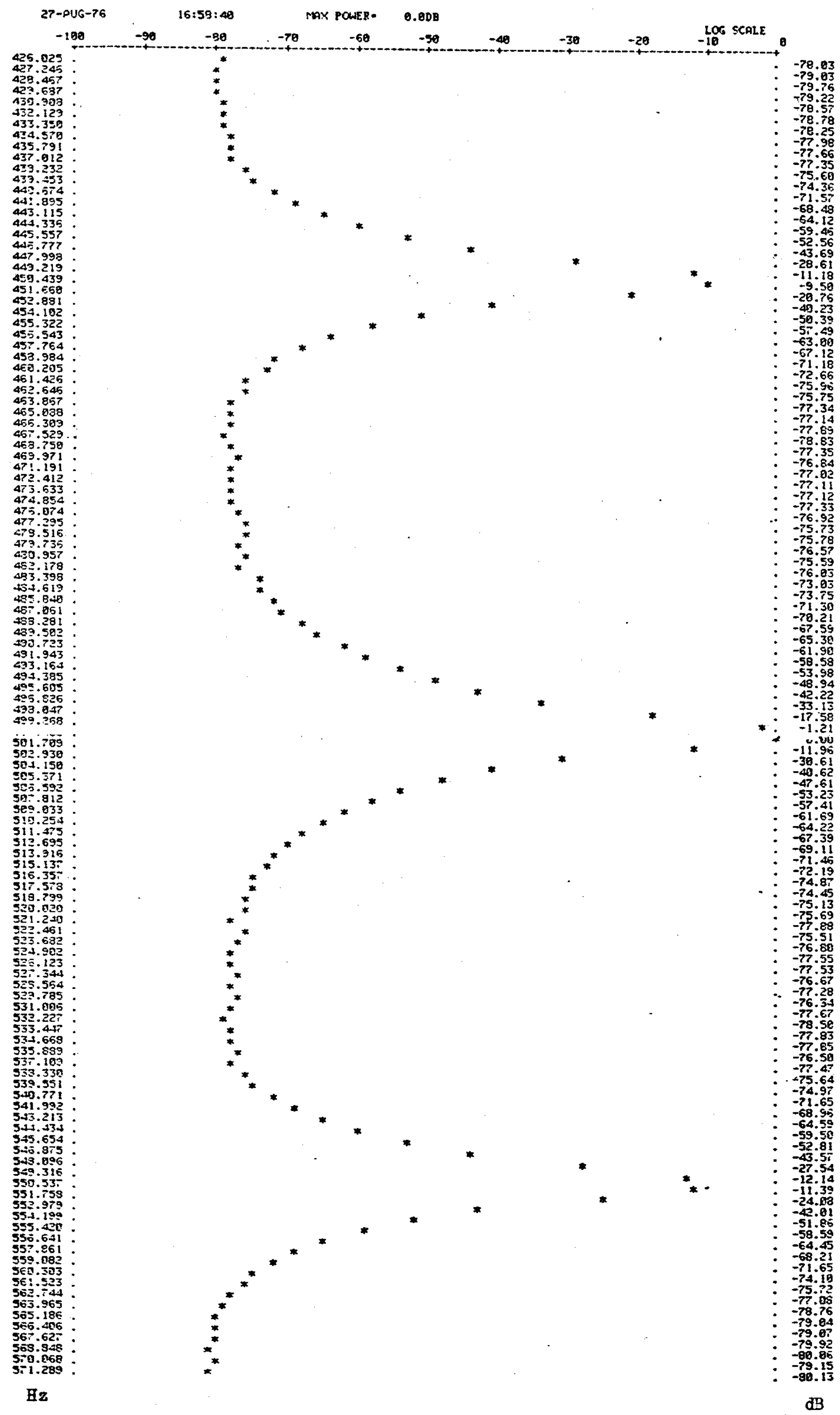


Figure 83. Averaged spectrum of the deramped signal in a 1.2 Hz resolution bandwidth

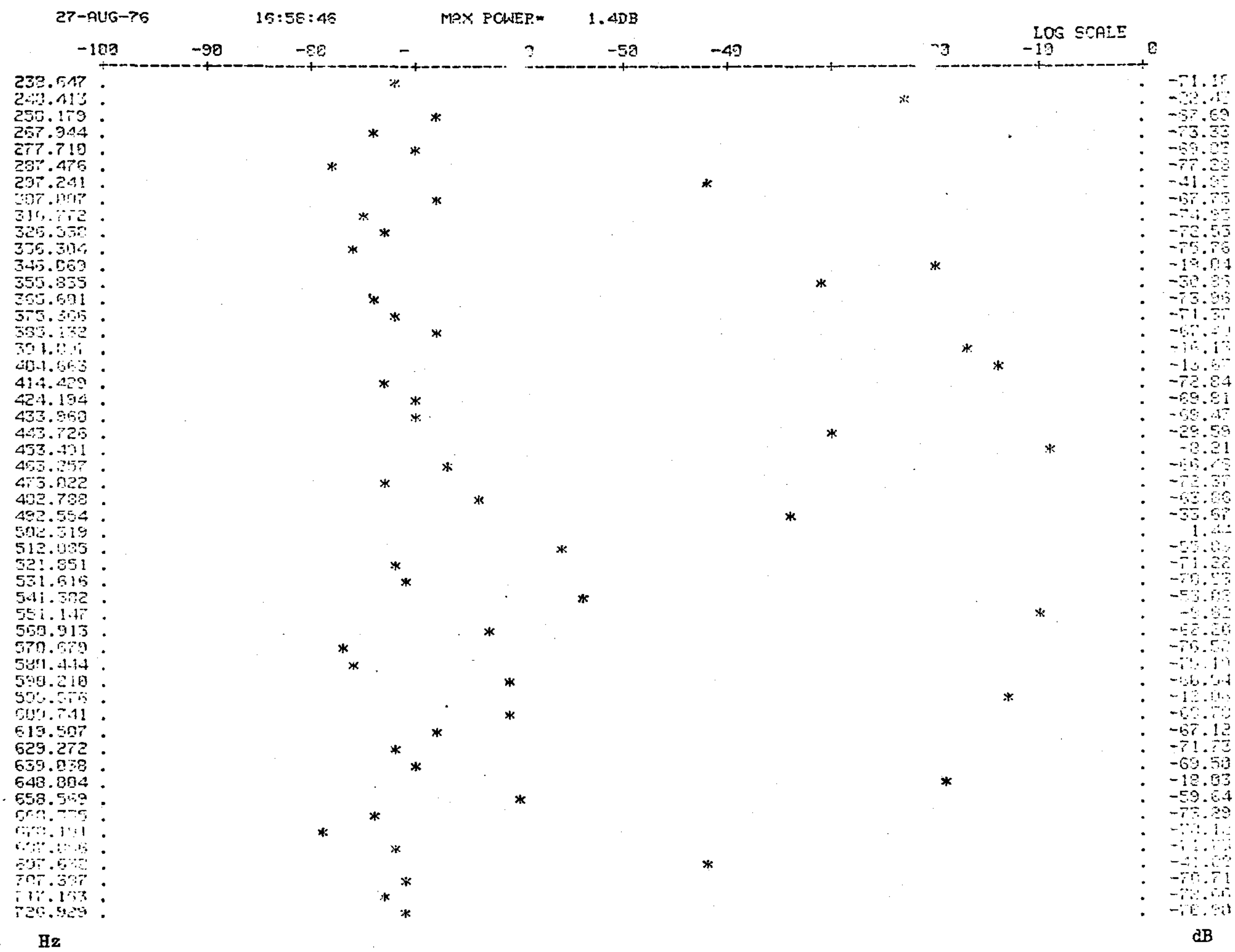


Figure 84. Unsmoothed spectrum of deramped signal in 9.77 Hz resolution bandwidth (50 Hz case)

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SPECTRAL LIST OF DERAMPED SIGNALS;'EACH LSG UNDER COMPUTER CONTROL

PARAMETERS
J= 407
K= 41
PPF= 59.93HZ
FREQ=10700 -5000HZ
SWEEP RATE=1000KHZ/SEC
DELAY= 5000MICROSEC
BW=16687.00

-77	-83	-80	-80	-81	-77	-77	-77	-74	-77	-80	-82	-77	-79	-80
-76	-81	-92	-77	-76	-78	-83	-78	-71	-75	-77	-76	-81	-78	-82
-77	-89	-74	-74	-77	-73	-76	-80	-91	-87	-76	-77	-88	-73	-71
-86	-82	-86	-88	-81	-77	-76	-83	-76	-73	-79	-80	-76	-76	-78
-76	-74	-73	-77	-76	-81	-84	-80	-81	-82	-80	-79	-75	-73	-77
-88	-88	-74	-76	-83	-77	-78	-79	-85	-93	-75	-74	-90	-82	-79
-93	-81	-77	-76	-75	-91	-75	-74	-78	-86	-75	-77	-82	-73	-76
-88	-101	-82	-75	-80	-86	-78	-79	-82	-84	-80	-80	-75	-74	-78
-80	-85	-85	-79	-77	-75	-81	-84	-81	-74	-73	-83	-90	-71	-70
-78	-81	-79	-106	-93	-91	-83	-91	-81	-95	-77	-84	-79	-77	-74
-77	-80	-74	-75	-77	-71	-76	-88	-84	-85	-79	-76	-77	-89	-86
-88	-85	-87	-84	-89	-84	-78	-79	-86	-90	-78	-76	-82	-77	-74
-98	-86	-80	-75	-76	-81	-80	-84	-94	-82	-79	-78	-78	-76	-81
-79	-79	-80	-79	-81	-81	-77	-77	-86	-78	-78	-84	-80	-76	-72
-76	-81	-83	-82	-79	-76	-84	-94	-85	-81	-80	-74	-74	-80	-82
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-75	-72	-80	-78	-71	-69	-74	-82	-80	-81	-82	-81	-75	-69	-70
-83	-76	-75	-78	-79	-84	-76	-82	-84	-81	-78	-75	-75	-76	-84
-77	-80	-76	-77	-84	-78	-87	-79	-82	-78	-88	-85	-78	-83	-75
-78	-91	-84	-77	-77	-88	-82	-82	-79	-95	-77	-84	-82	-80	-74
-77	-84	-86	-82	-87	-80	-91	-76	-80	-83	-80	-81	-78	-79	-80
-96	-85	-79	-79	-91	-81	-78	-78	-81	-89	-76	-73	-78	-84	-79
-96	-81	-77	-76	-77	-82	-83	-84	-81	-76	-82	-82	-82	-74	-70
-77	-77	-78	-76	-77	-76	-72	-74	-85	-81	-75	-77	-80	-91	-75
-84	-83	-77	-86	-77	-74	-78	-93	-81	-74	-72	-74	-76	-79	-74
-87	-80	-85	-87	-81	-82	-77	-81	-81	-79	-81	-76	-76	-77	-73
-85	-79	-75	-76	-82	-74	-71	-82	-73	-74	-86	-80	-78	-79	-74
-80	-75	-76	-72	-77	-80	-81	-83	-81	-78	-83	-80	-78	-85	-78
-79	-81	-72	-69	-73	-72	-72	-69	-72	-71	-74	-78	-90	-76	-70
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-77	-82	-97	-83	-77	-82	-78	-74	-77	-75	-72	-85	-81	-75	-73
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-78	-73	-71	-74	-79	-76	-81	-85	-82	-77	-73	-73	-76	-80	-78
-73	-75	-100	-86	-82	-77	-78	-75	-73	-89	-79	-72	-70	-80	-82
-79	-75	-79	-83	-84	-87	-88	-86	-84	-83	-87	-93	-85	-80	-76
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-79	-77	-76	-79	-80	-81	-77	-85	-84	-79	-79	-82	-83	-86	-80
-74	-90	-90	-81	-78	-76	-80	-82	-94	-87	-84	-91	-73	-70	-74
-77	-79	-84	-79	-77	-73	-78	-80	-79	-86	-81	-76	-78	-80	-81
-77	-74	-75	-87	-79	-89	-80	-80	-74	-76	-78	-79	-78	-81	-73
-81	-80	-77	-79	-73	-73	-70	-75	-84	-81	-80	-89	-81	-79	-73
-79	-95	-77	-79	-81	-77	-79	-83	-106	-78	-73	-75	-77	-73	-73
-77	-86	-83	-76	-75	-76	-74	-76	-88	-77	-74	-82	-80	-76	-83
-71	-83	-73	-73	-75	-70	-85	-76	-78	-74	-73	-76	-75	-68	-81
-83	-78	-74	-72	-84	-81	-82	-77	-86	-72	-70	-77	-80	-94	-80
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-86	-83	-88	-76	-77	-78	-73	-74	-75	-74	-76	-82	-90	-77	-71
-76	-79	-85	-93	-81	-91	-87	-83	-75	-75	-82	-83	-74	-84	-74
-76	-79	-89	-80	-76	-74	-73	-77	-92	-83	-89	-80	-79	-87	-75
-80	-81	-92	-92	-88	-80	-74	-76	-83	-92	-96	-88	-82	-89	-86

DBS	HISTLO	HISTHI
-51	0	0
-52	0	0
-53	0	0
-54	0	0
-55	0	0
-56	0	0
-57	0	0
-58	0	0
-59	0	0
-60	0	0
-61	0	0
-62	0	0
-63	0	0
-64	0	0
-65	0	0
-66	0	0
-67	0	0
-68	0	1
-69	5	2
-70	5	6
-71	7	7
-72	11	13
-73	19	31
-74	35	35
-75	39	27
-76	53	51
-77	57	47
-78	48	41
-79	45	47
-80	276	292

Figure 85. Computer printout of noise floor levels in specified segments of the deramped signal spectrum (60 Hz case)

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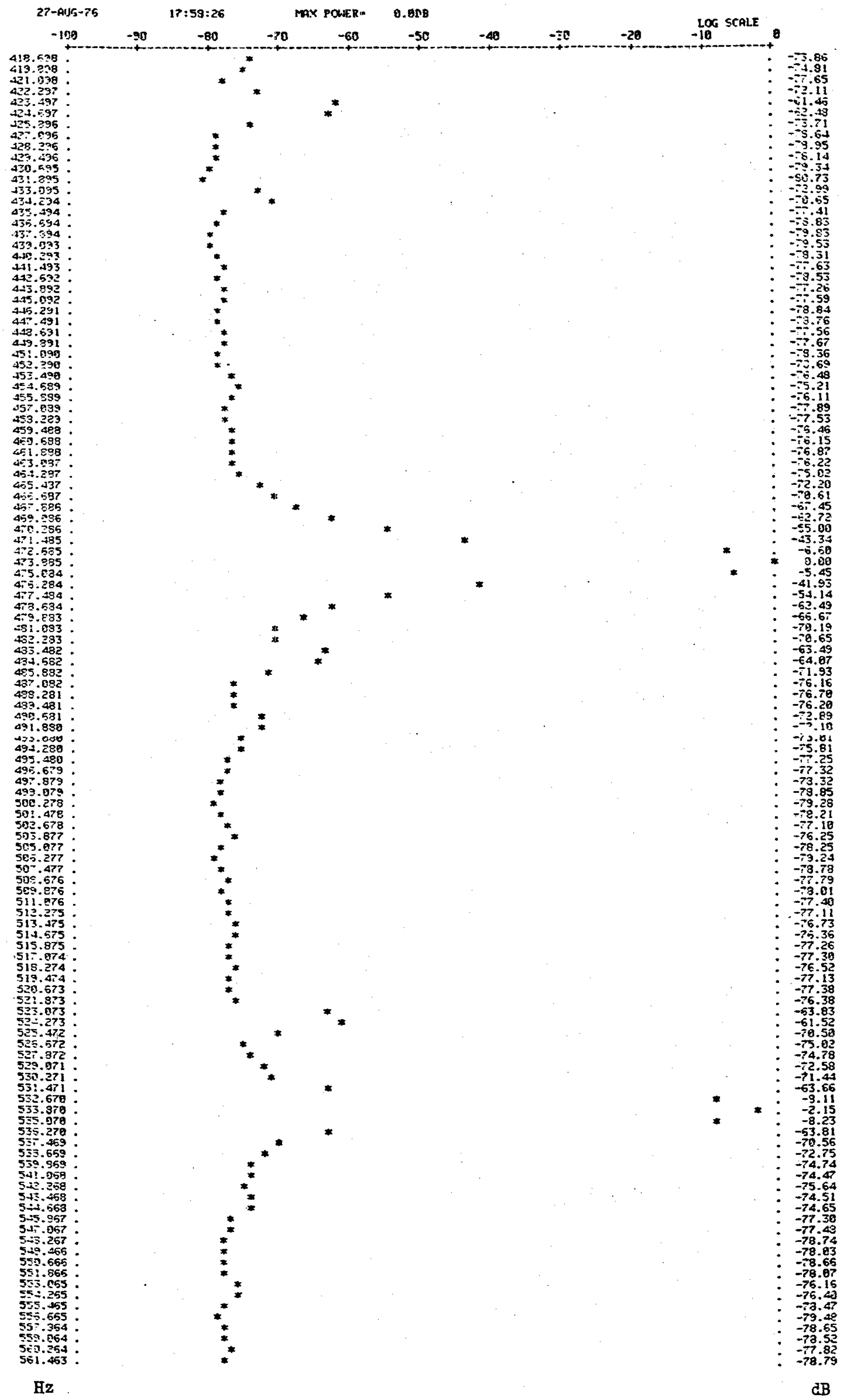


Figure 86. Averaged spectrum of the deramped signal in a 1.2 Hz resolution bandwidth (60 Hz case)

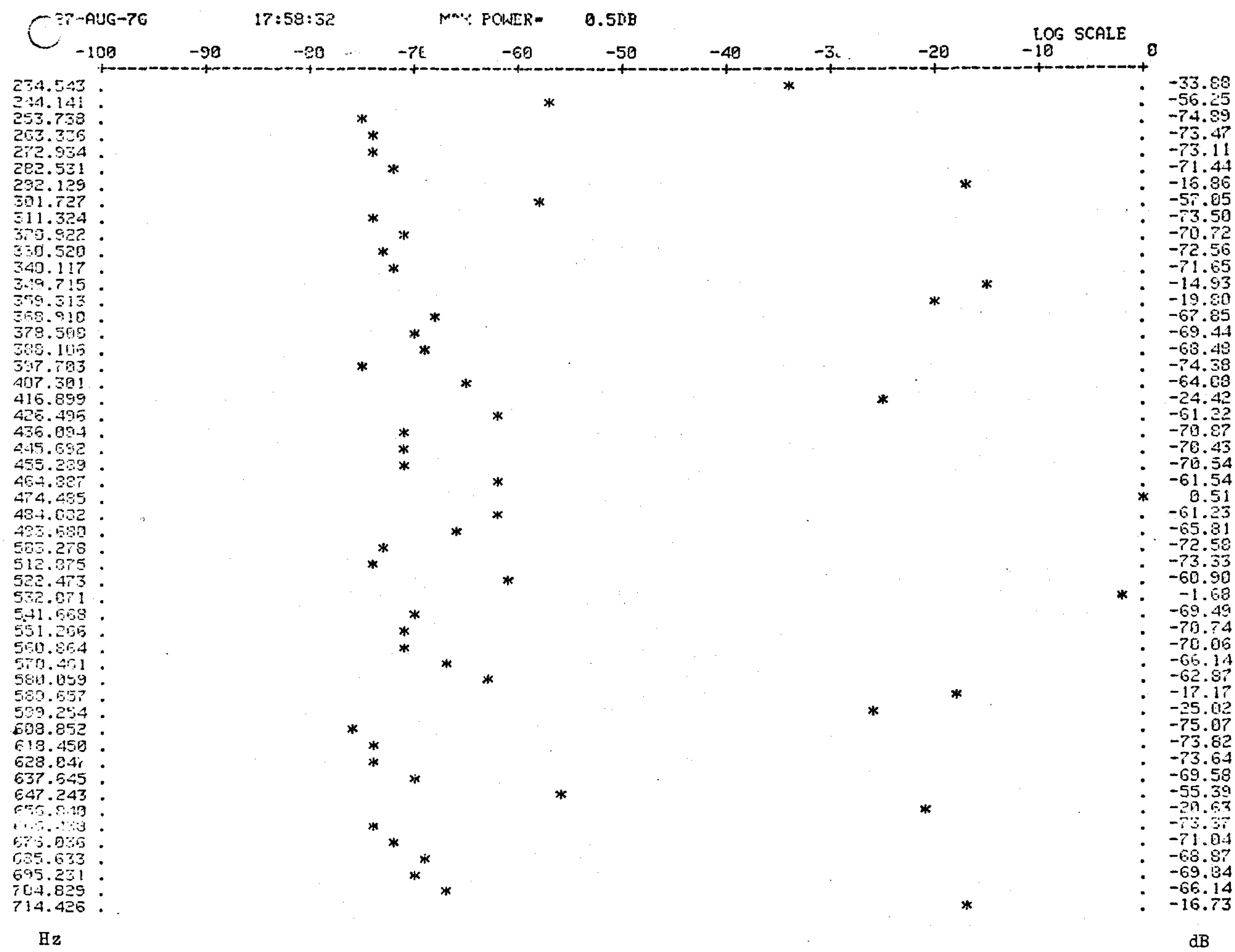
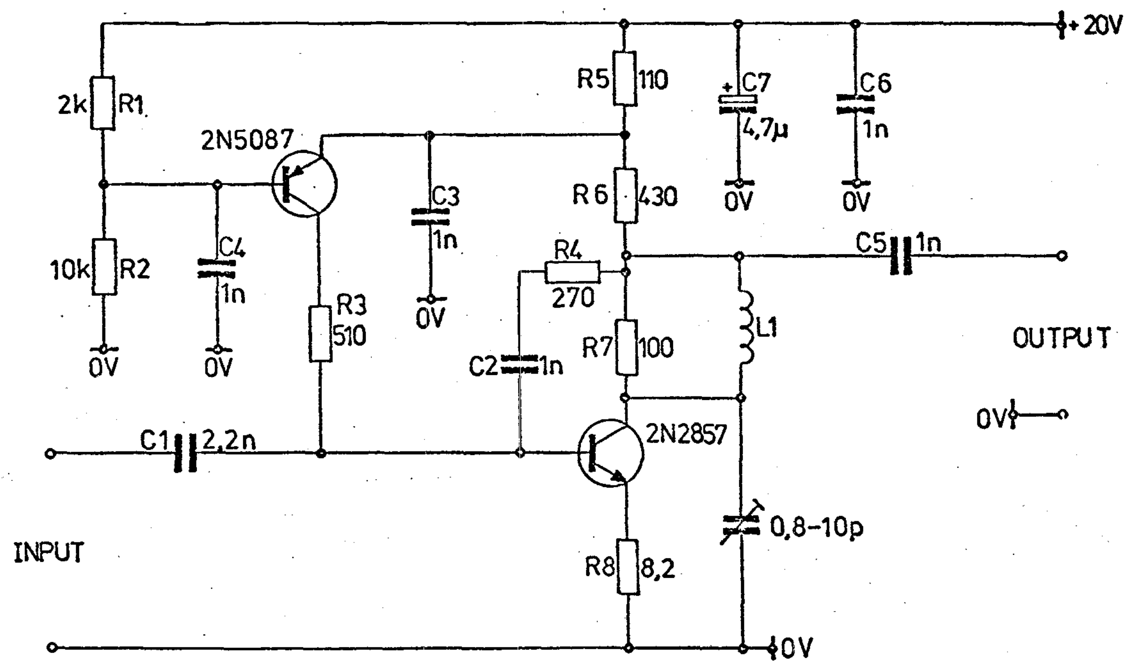


Figure 87. Unsmoothed spectrum of the deramped signal in a 9.77 Hz resolution bandwidth (60 Hz case)



NOTE:
L1 4 TURNS 28G. TCW WOUND ON R7

Figure 88. Broadband linear amplifier

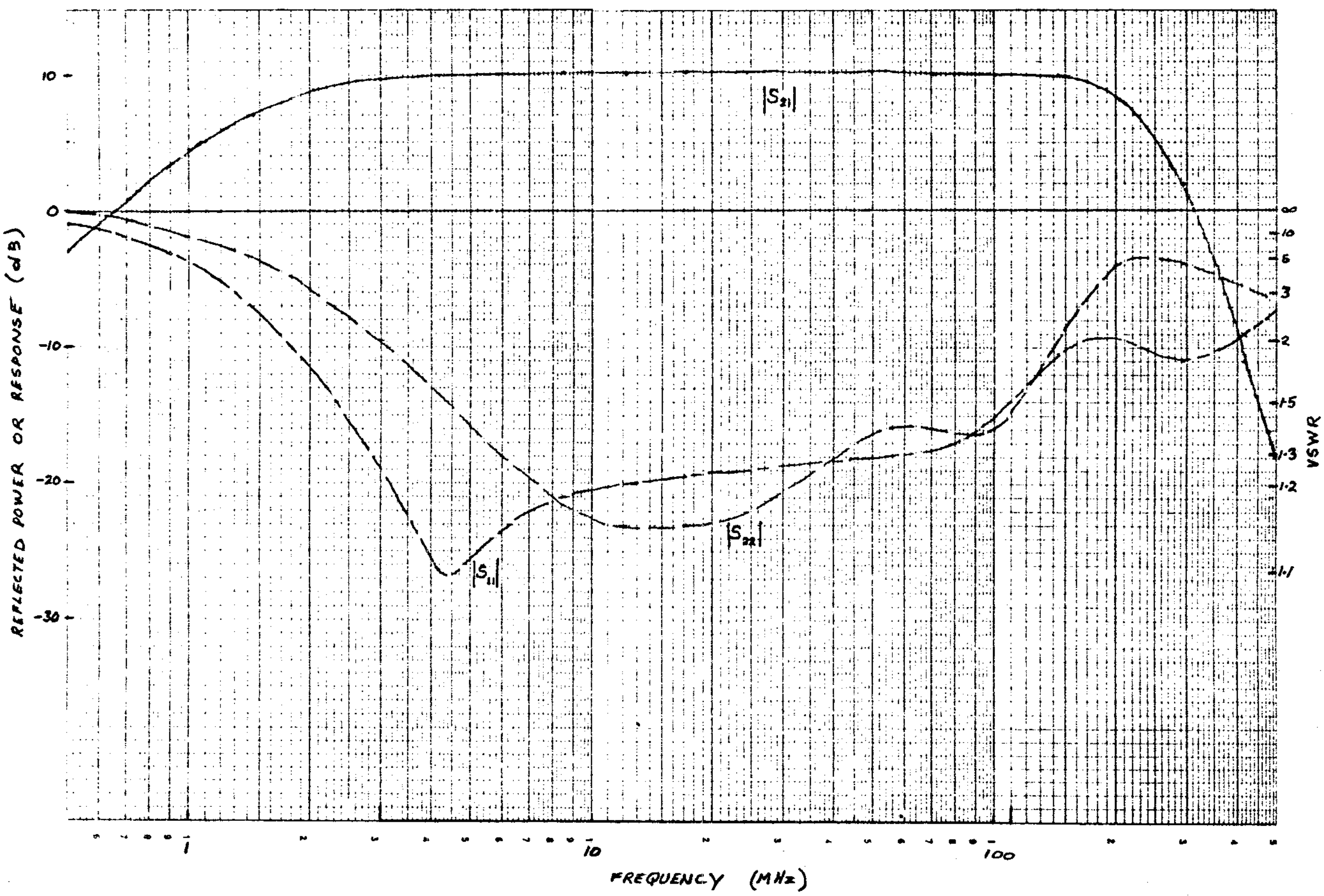


Figure 89. Performance of 10 dB broadband amplifier

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